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UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF MICHIGAN

TI GROUP AUTOMOTIVE SYSTEMS, LLC, a Delaware Limited Liability Company,

Plaintiff,

v.

PERFORMANCE AFTERMARKET PARTS GROUP, LTD, a Texas Limited Partnership

Defendant.

JUDGE : Edmunds, Nancy G.
DECK : S. Division Civil Deck
DATE : 11/10/2005 @ 14:11:41
CASE NUMBER : 2:05CV74325
cmp ti group automotive v. performance , tam

MAGISTRATE JUDGE PEPE

COMPLAINT FOR PATENT INFRINGEMENT AND DEMAND FOR JURY TRIAL

Plaintiff, TI GROUP AUTOMOTIVE SYSTEMS, LLC (hereinafter "TI GROUP") by its attorneys Butzel Long, as and for its Complaint against defendant PERFORMANCE AFTERMARKET PARTS GROUP, LTD (hereinafter "PERFORMANCE AFTERMARKET"), allege as follows:

I. PARTIES, JURISDICTION AND VENUE

1. This is a civil action arising under the patent laws of the United States, more particularly 35 U.S.C. §§ 271, 281, 283, 284, and 285.

2. This Court has jurisdiction over this action pursuant to 28 U.S.C. §§ 1331, 1338(a), and/or 1338(b), in that it arises under the laws of the United States relating to patents;

under 28 U.S.C. § 1332, in that the matter in controversy exceeds the sum or value of $75,000, exclusive of interest and costs, and is between citizens of different states.

3. Venue is proper in this judicial district pursuant to 28 U.S.C. § 1391 (a), (b) and/or (c), in that PERFORMANCE AFTERMARKET conducts substantial business within this judicial district and a substantial part of the events or omissions giving rise to the claims occurred within this judicial district.

4. Venue is proper in this Judicial District pursuant to 28 U.S.C. §§ 1391(b), 1391(c) & 1400(b).

5. On information and belief, personal jurisdiction over PERFORMANCE AFTERMARKET is properly founded on PERFORMANCE AFTERMARKET actively operating businesses and committing acts of infringement, contributory infringement and inducing infringement within the Eastern District of Michigan.

6. Plaintiff TI GROUP is a Delaware limited liability company with a principal place of business located at 12345 East Nine Mile Road, Warren, Michigan.

7. On information and belief, defendant PERFORMANCE AFTERMARKET is a limited partnership organized and existing under the laws of the State of Texas, having its principal place of business at 12999 Executive Drive, Sugar Land, Texas.

8. Plaintiff TI GROUP (including its divisions) is a leading manufacturer and seller of vehicle fuel system components, including fuel pumps and fuel pump modules. Plaintiff TI GROUP is well known in the industry as a maker of superior quality vehicle fuel system components.

9. On information and belief, Defendant PERFORMANCE AFTERMARKET makes and/or sells vehicle fuel system components, including fuel pumps and fuel pump modules and has offered some of these components within this judicial district.

II. COUNT I FOR PATENT INFRINGEMENT

INFRINGEMENT OF THE '714 PATENT

10. Plaintiff TI GROUP realleges Paragraphs 1-9 as if set forth herein.

11. TI GROUP is the owner of all right, title and interest in and to United States Patent No. 4,860,714 for IN-TANK FUEL PUMP ASSEMBLY FOR FUEL-INJECTED ENGINES, which duly and legally issued on August 29, 1989 ("the '714 Patent"). A copy of the '714 Patent is attached hereto as Exhibit A.

12. The inventions described and claimed in the '714 Patent are related to an in-tank fuel pump assembly for fuel-injected engines which includes a reservoir having a supply port for supplying fuel to the engine and a return port for receiving fuel returning from the engine.

13. Defendant PERFORMANCE AFTERMARKET has been and still is infringing the '714 Patent by making, offering for sale, selling and using a fuel system component embodying the patented invention, and will continue to do so unless enjoined by this Court.

14. Upon information and belief, PERFORMANCE AFTERMARKET offers for sale and sells a fuel system component embodying the patented inventions in this Judicial District.

15. Upon information and belief, the infringement of the '714 Patent by PERFORMANCE AFTERMARKET is willful, wanton, deliberate, without license, and with full knowledge of TI GROUP's rights.

16. TI GROUP has been damaged by the infringement of PERFORMANCE AFTERMARKET in an amount to be determined at trial. Unless restrained and enjoined by this Court, PERFORMANCE AFTERMARKET will continue to infringe the '714 Patent resulting in substantial, continuing, and irreparable damage to TI GROUP for which it has no adequate remedy at law.

17. This case is "exceptional" within the meaning of 35 U.S.C. § 285.

III. COUNT II FOR PATENT INFRINGEMENT

INFRINGMENT OF THE '701 PATENT

18. Plaintiff TI GROUP realleges Paragraphs 1-17 as if set forth herein.

19. TI GROUP is the owner of all right, title and interest in and to United States Patent No. 5,452,701 for TURBINE FUEL PUMP WITH FUEL JET, which duly and legally issued on September 26, 1995 ("the '701 Patent"). A copy of the '701 Patent is attached hereto as Exhibit B.

20. The inventions described and claimed in the '701 Patent are related to an electrically operated fuel pump for vehicles which utilizes a turbine pump rotor operating in an annular pumping channel having circumferentially spaced inlet and outlet ports.

21. Defendant PERFORMANCE AFTERMARKET has been and still is infringing the '701 Patent by making, offering for sale, selling and using a fuel system component embodying the patented invention, and will continue to do so unless enjoined by this Court.

22. Upon information and belief, PERFORMANCE AFTERMARKET offers for sale and sells a fuel system component embodying the patented inventions in this Judicial District.

23. Upon information and belief, the infringement of the '701 Patent by PERFORMANCE AFTERMARKET is willful, wanton, deliberate, without license, and with full knowledge of TI GROUP's rights.

24. TI GROUP has been damaged by the infringement of PERFORMANCE AFTERMARKET in an amount to be determined at trial. Unless restrained and enjoined by this Court, PERFORMANCE AFTERMARKET will continue to infringe the '701 Patent resulting in substantial, continuing, and irreparable damage to TI GROUP for which it has no adequate remedy at law.

25. This case is "exceptional" within the meaning of 35 U.S.C. § 285.

IV. COUNT III FOR PATENT INFRINGEMENT

INFRINGMENT OF THE '819 PATENT

26. Plaintiff TI GROUP realleges Paragraphs 1-25 as if set forth herein.

27. TI GROUP is the owner of all right, title and interest in and to United States No. 6,227,819, which duly and legally issued on May 8, 2001 ("the '819 Patent"). A copy of the '819 Patent is attached hereto as Exhibit C.

28. The inventions described and claimed in the '819 Patent are related to a fuel pump assembly for drawing fuel from a reservoir and supplying that fuel to an engine and including a fuel pumping module and an electric motor supported in a pump housing.

29. Defendant PERFORMANCE AFTERMARKET has been and still is infringing the '819 Patent by making, offering for sale, selling and using a fuel system component embodying the patented invention, and will continue to do so unless enjoined by this Court.

30. Upon information and belief, PERFORMANCE AFTERMARKET offers for sale and sells a fuel system component embodying the patented inventions in this Judicial District.

31. Upon information and belief, the infringement of the '819 Patent by PERFORMANCE AFTERMARKET is willful, wanton, deliberate, without license, and with full knowledge of TI GROUP's rights.

32. TI GROUP has been damaged by the infringement of PERFORMANCE AFTERMARKET in an amount to be determined at trial. Unless restrained and enjoined by this Court, PERFORMANCE AFTERMARKET will continue to infringe the '819 Patent resulting in substantial, continuing, and irreparable damage to TI GROUP for which it has no adequate remedy at law.

33. This case is "exceptional" within the meaning of 35 U.S.C. § 285.

34. TI GROUP has no adequate remedy at law for PERFORMANCE AFTERMARKET's wrongful activities.

35. PERFORMANCE AFTERMARKET's wrongful activities constitute willful and intentional infringement and disregard of TI GROUP's proprietary rights, and were commenced and have continued in spite of PERFORMANCE AFTERMARKET's knowledge that such activities were and are in direct contravention of TI GROUP's rights.

WHEREFORE, Plaintiff TI GROUP, prays for judgment against defendant PERFORMANCE AFTERMARKET as follows:

A. A judgment that U.S. Patent No. 4,860,714 is being infringed by defendant PERFORMANCE AFTERMARKET;

B. A judgment that U.S. Patent No. 5,452,701 is being infringed by defendant PERFORMANCE AFTERMARKET;

C. A judgment that U.S. Patent No. 6,227,819 is being infringed by defendant PERFORMANCE AFTERMARKET;

D. That defendant PERFORMANCE AFTERMARKET, its officers, agents, servants, employees and parties in privity, and those persons in active concert or participation with them who receive actual notice of the order by personal service or otherwise be joined preliminarily during the pendency of this suit and permanently thereafter from directly or indirectly making, causing to be made, in any way using or causing to be used, or selling or causing to be sold, any article of manufacture or product infringing one or more claims of U.S. Patent No. 4,860,714, U.S. Patent No. 5,452,701, and U.S. Patent No. 6,227,819 or from inducing or contributing to the infringement of any of said patent claims in any way whatsoever;

E. That the infringement to which the foregoing injunctive relief provided by paragraph D include, but not be limited to manufacturing, making, providing, assembling, using, installing, selling, distributing, promoting, contracting and/or advertising for sale

in the United States the aforesaid fuel system component or any service to be performed in connection with such product, including knowingly aiding, abetting or assisting in connection with such product in any way;

F. That this Court award plaintiff TI GROUP damages adequate to compensate for acts of infringement of defendant PERFORMANCE AFTERMARKET together with prejudgment interest thereon, as provided for by 35 U.S.C. §284;

G. That said damages be increased to three times the amount to be assessed, in accordance with 35 U.S.C. §284;

H. That plaintiff TI GROUP be awarded its costs and attorneys' fees, as provided for by 35 U.S.C. §285; and

I. That plaintiff TI GROUP be awarded such other and further relief against defendant PERFORMANCE AFTERMARKET as this Court appears just and proper under the circumstances.

DEMAND FOR JURY TRIAL

Plaintiff TI GROUP hereby demands a trial by jury.

Dated: November 10, 2005

BUTZEL LONG P.C.

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A.

United States Patent [19]

Bucci

[11] Patent Number: 4,860,714

[45] Date of Patent: Aug. 29, 1989

[54] IN-TANK FUEL PUMP ASSEMBLY FOR FUEL-INJECTED ENGINES

[75] Inventor: George H. Bucci, Tolland, Conn.

[73] Assignee: Whitehead Engineered Products, Inc., Meriden, Conn.

[21] Appl. No.: 898,432

[22] Filed: Aug. 20, 1986

[51] Int. Cl.^{4} F02M 39/00

[52] U.S. Cl. 123/514; 123/509; 137/263

[58] Field of Search 123/514, 509, 516, 495; 137/263, 113, 255

[56] References Cited

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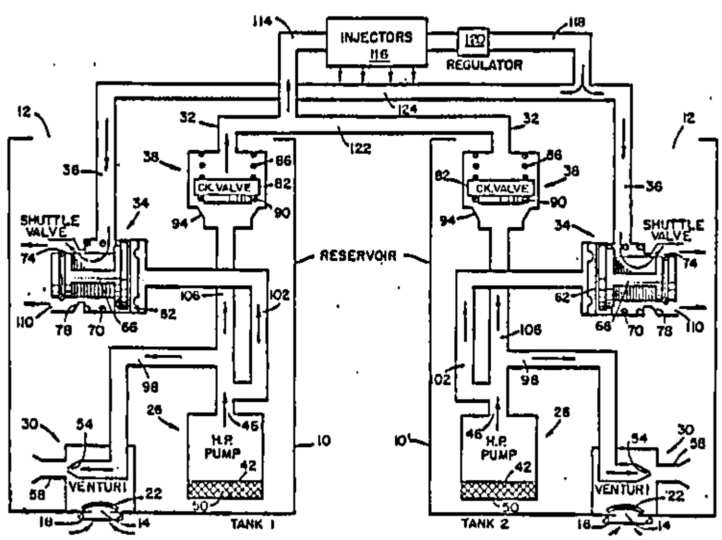
Primary Examiner—Carl Stuart Miller

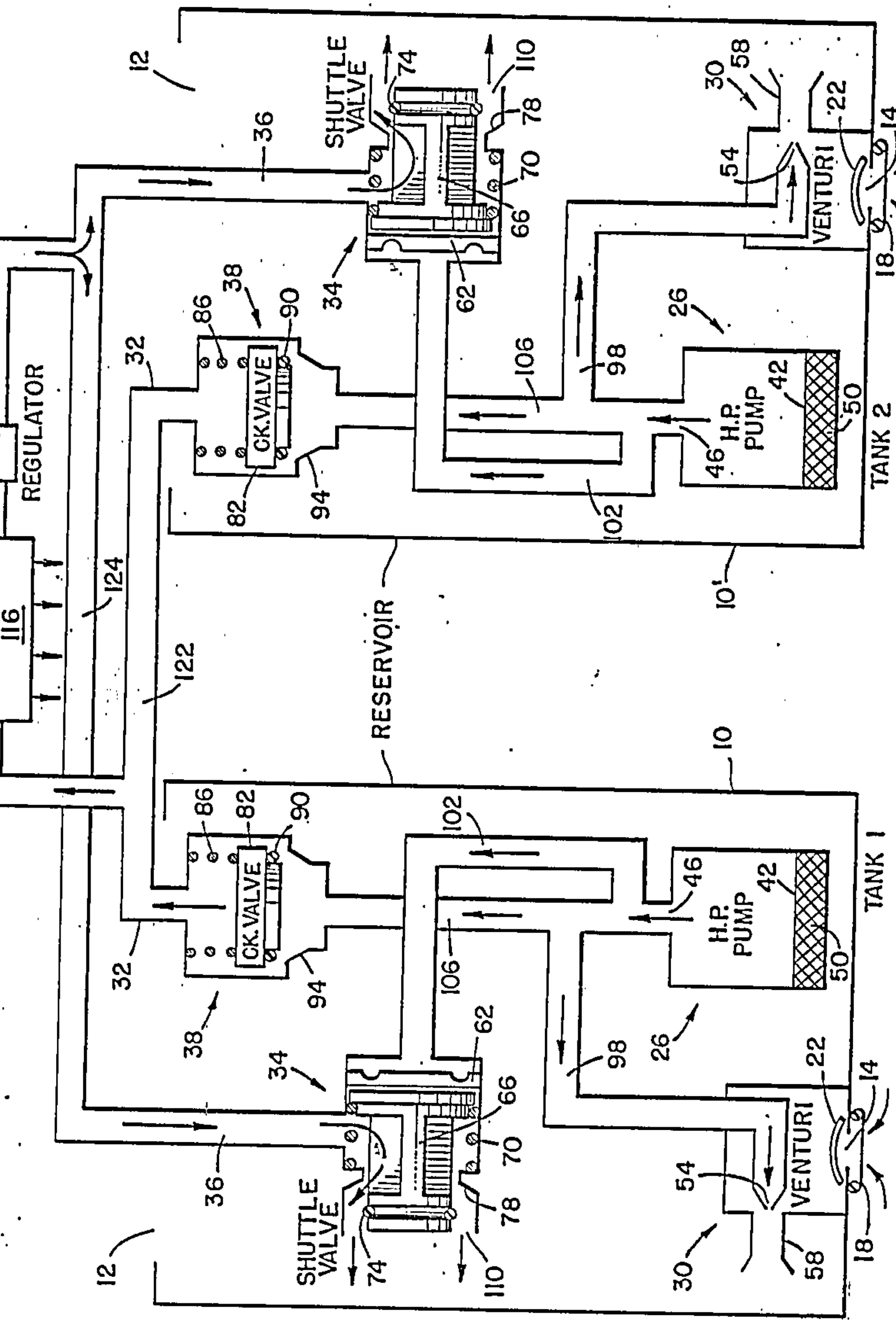
Attorney, Agent, or Firm—Maurice M. Klee

[57] ABSTRACT

An in-tank, fuel pump assembly for fuel-injected engines is provided which includes a reservoir having a supply port for supplying fuel to the engine and a return port for receiving fuel returning from the engine. Within the reservoir are (1) an electrically-operated, high pressure pump, (2) a jet pump located at the bottom of the reservoir for entraining fuel into the reservoir, (3) a valve associated with the return port, and (4) a valve associated with the supply port. The output of the high pressure pump is routed to the jet pump and to the two valves whereby when the high pressure pump is not operating, both valves are closed, and when the high pressure pump is operating, both valves are open and the jet pump entrains fuel into the reservoir. The jet pump is sized to entrain more fuel into the reservoir than leaves the reservoir through the supply port thus producing a net flow of fuel from the bottom to the top of the reservoir. As a result of this flow and the arrangement of the various components of the assembly, cool fuel from the main fuel tank is supplied to the engine rather than hot fuel returning from the engine through the return port, thus avoiding the hot fuel problems experienced in the prior art.

8 Claims, 6 Drawing Sheets

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REGULATOR
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FIG. 1.

FIG. 2.

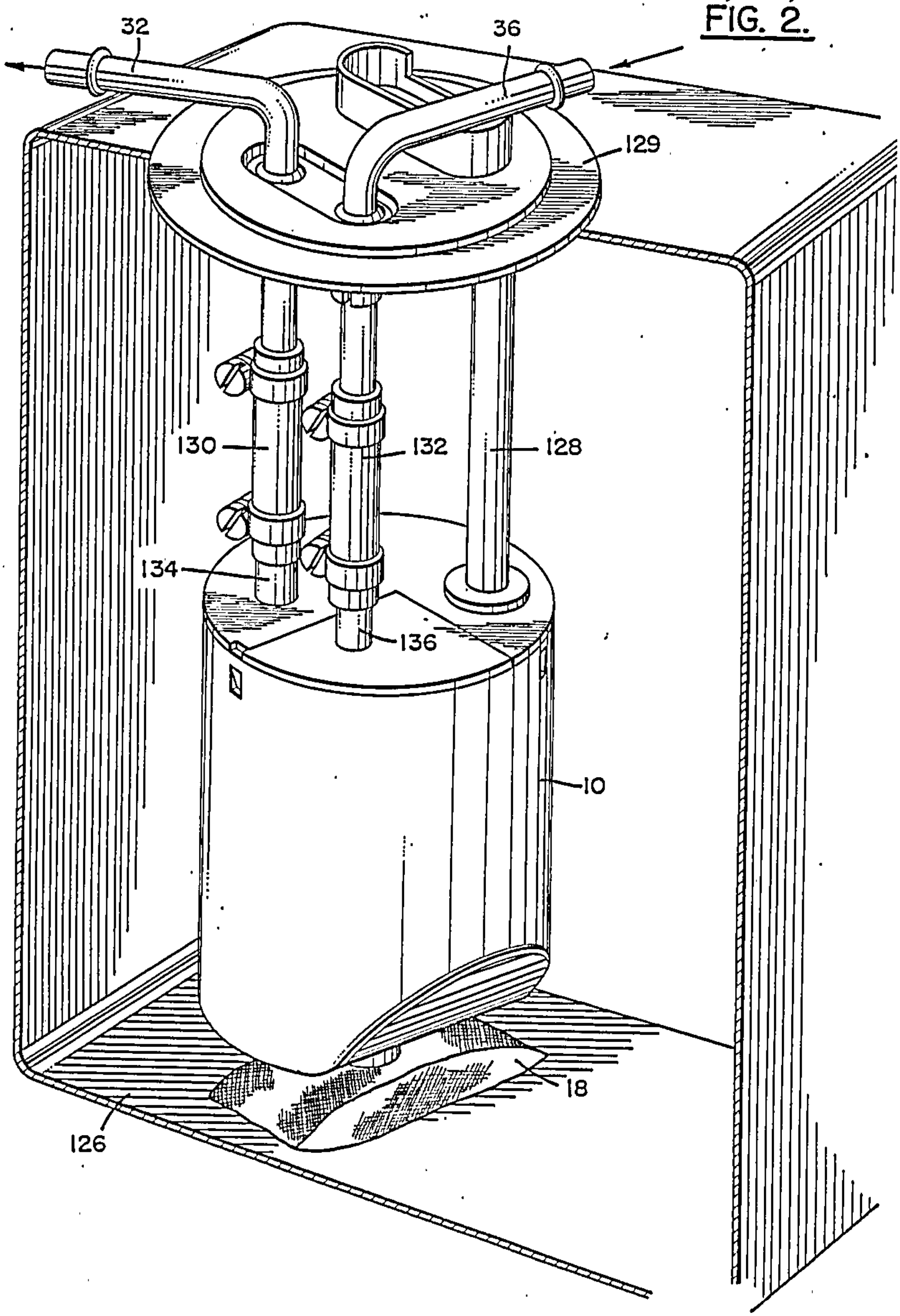

FIG. 3.

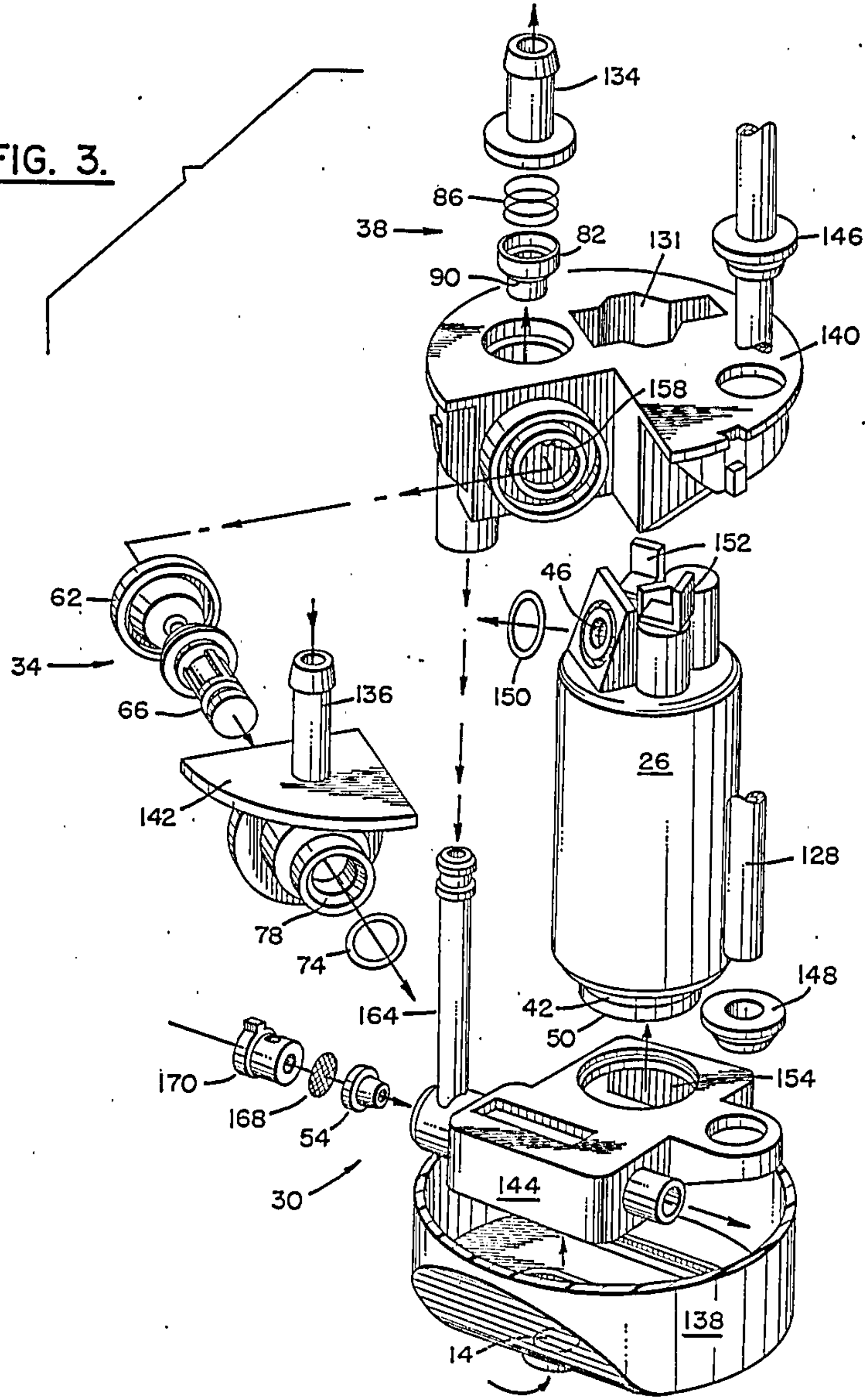
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FIG. 4.

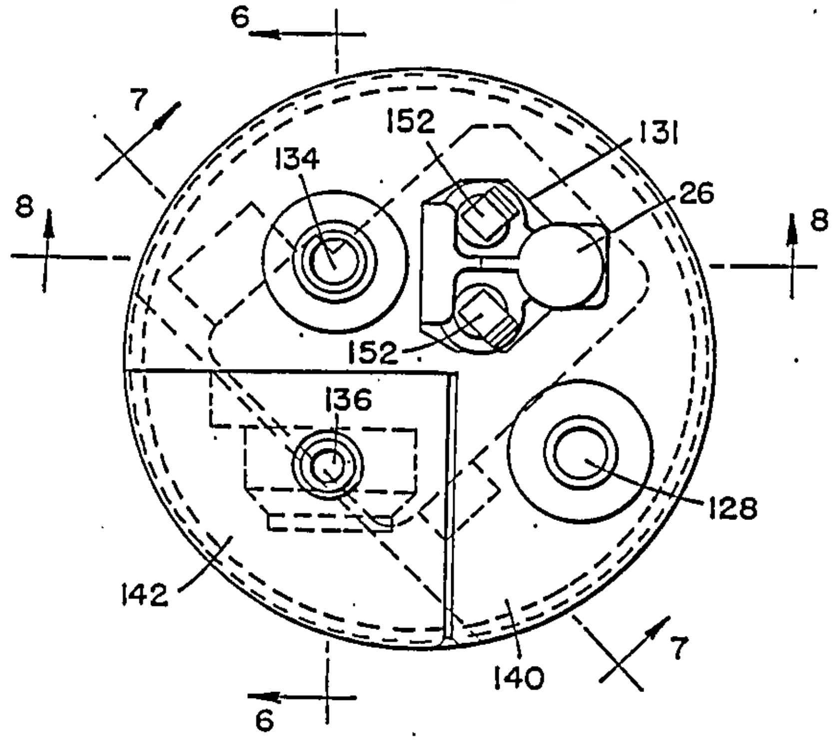

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FIG. 7.

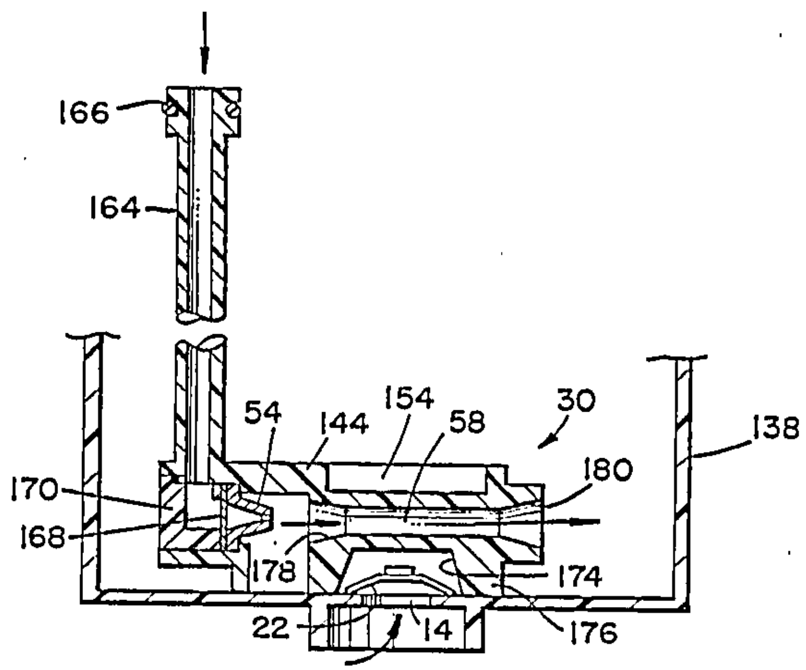

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FIG. 6.

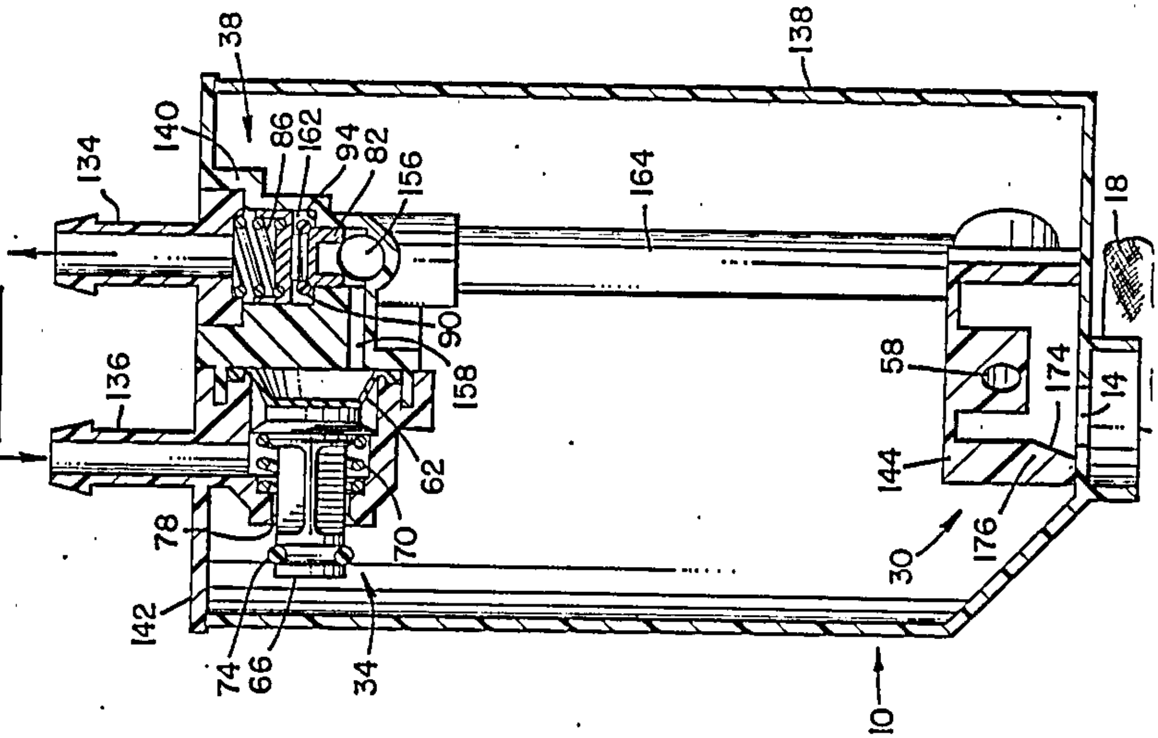


FIG. 5.

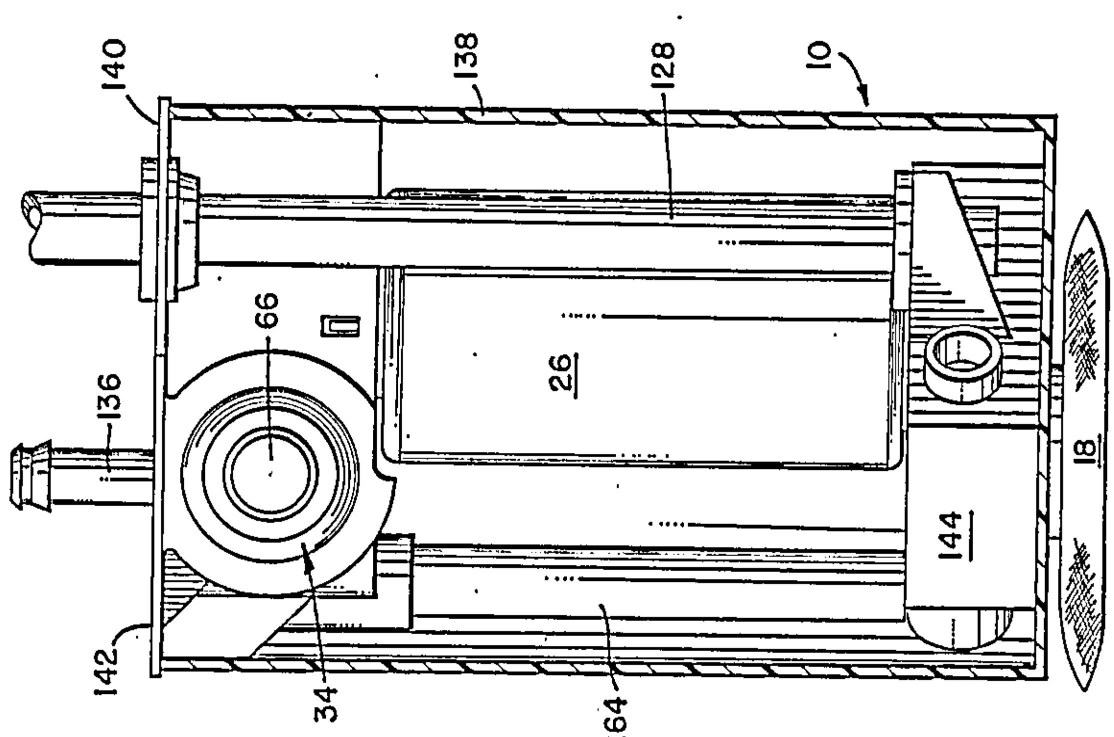


FIG. 8.

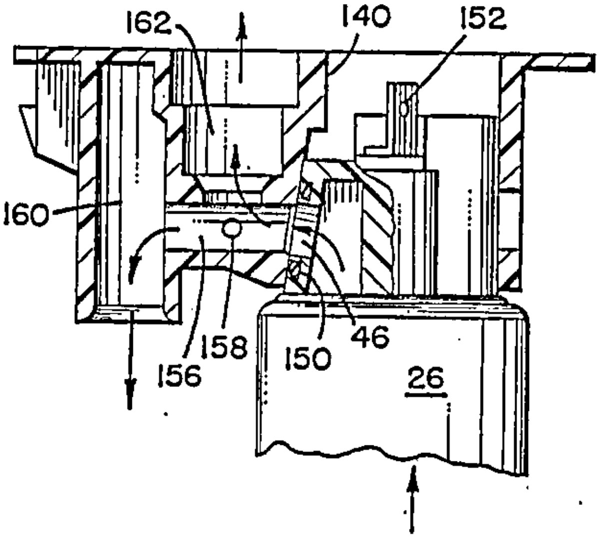
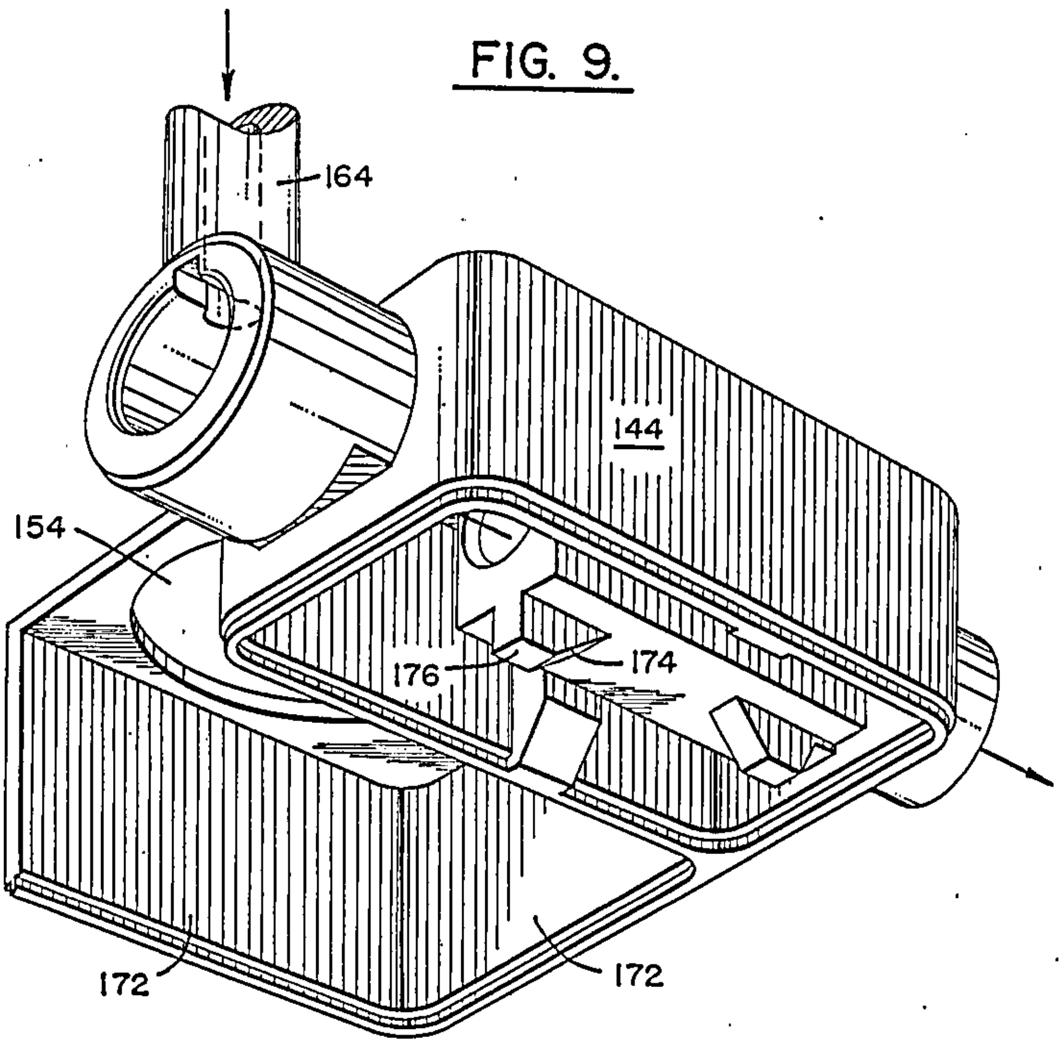


FIG. 9.



IN-TANK FUEL PUMP ASSEMBLY FOR FUEL-INJECTED ENGINES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to fuel-injected engines and, in particular, to in-tank, high pressure, fuel pump assemblies for use with such engines.

2. Description of the Prior Art

In a fuel-injected engine, fuel is supplied at a relatively high pressure to one or more injectors which are connected directly to the engine cylinders or to an intake manifold leading to the cylinders. In the prior art, two electrically driven pumps have typically been used to deliver fuel to the injectors: a low pressure pump either near or in the vehicle's fuel tank and a high pressure pump connected to the injectors. For vehicles having two fuel tanks, e.g., medium duty and larger trucks, off-road vehicles, and the like, an additional low pressure pump has been used for the second tank.

In order to reduce the complexity and cost, including the cost of assembly, of such systems, efforts have been made to eliminate the low pressure pump by placing the high pressure pump directly in the vehicle's fuel tank. The primary problems raised by this approach have been in the area of insuring that there is a constant supply of fuel at the intake to the high pressure pump. Specifically, the problem has been to supply the high pressure pump with fuel under low fuel conditions and during times when the vehicle is navigating a sharp turn, traveling over a steep incline, or after the vehicle has been parked on an incline for an extended period of time.

Various approaches have been tried to solve the foregoing problems. For example, the high pressure pump has been housed in a reservoir within the vehicle's fuel tank and fuel has been routed to the reservoir to try to keep it filled. Specifically, the fuel returning from the engine has been routed to the reservoir, and, in some cases, the returning fuel has been used to power a jet pump to bring fuel into the reservoir from the main tank by means of Bernoulli forces.

To date, these approaches, rather than solving the problem, have raised problems of their own. In particular, filling the reservoir with fuel returning from the engine and then recycling that fuel back to the engine through the high pressure pump has been found to result in a "hot fuel" problem wherein the fuel is heated by the hot engine on each pass through the system and eventually reaches a temperature at which it can no longer be properly injected into the engine by the fuel-injection system.

As to using the returning fuel to power a jet pump, this approach has been found to be unsuccessful under conditions of high fuel consumption by the engine. Specifically, when the engine is using more fuel, less fuel is returned to the jet pump and thus less fuel is pulled into the reservoir by the jet pump. Accordingly, with time, the amount of fuel in the reservoir decreases, the temperature of the fuel supplied to the engine rises, and the overall performance of the engine and the fuel-injection system declines. Although theoretically it would be possible to solve this problem by using an oversized high pressure pump capable of supplying sufficient fuel to handle high fuel consumption conditions and still provide sufficient flow through the jet pump, the use of such a pump defeats the purpose of the change from the original two pump approach, namely, to reduce the overall cost of the system.

The present invention, as described in detail below, overcomes these problems by providing an in-tank, high pressure, fuel pump assembly which has minimal hot fuel problems and which entrains essentially a constant amount of fuel into its reservoir irrespective of the amount of fuel consumed by the vehicle's engine.

SUMMARY OF THE INVENTION

In view of the foregoing state of the art, it is an object of this invention to provide improved, in-tank, high pressure, fuel pump assemblies for use with fuel-injected vehicles. In particular, it is an object of this invention to provide such assemblies wherein hot fuel problems are minimized and wherein the performance of the assembly is essentially independent of the amount of fuel being consumed by the vehicle's engine.

It is a further object of the invention to provide in tank, high pressure, fuel pump assemblies wherein the supply and return lines connecting the assembly to the vehicle's engine are automatically closed when the vehicle's fuel pump is not in operation. It is another object of the invention to provide in-tank, high pressure, fuel pump assemblies for use with vehicles having multiple fuel tanks wherein fuel returning from the vehicle's engine is automatically routed to the fuel tank from which the fuel originated.

To achieve the foregoing and other objects, the invention in accordance with certain of its aspects provides apparatus for pumping fuel from a fuel tank to an engine comprising:

(a) a supply port leading from the apparatus to the engine;

(b) a fuel reservoir which includes an opening for connecting the interior of the reservoir to the interior of the fuel tank;

(c) means for mounting the reservoir in the fuel tank;

(d) pumping means for pumping fuel into the reservoir, said means being located within the reservoir in the region of the opening and including a nozzle and a venturi tube in alignment with the nozzle, the passage of fuel out of the nozzle and through the venturi tube causing fuel to be entrained through the opening into the interior of the reservoir:

(e) a high pressure pump having an inlet connected to the interior of the reservoir and a high pressure outlet; and

(f) means for routing a first portion of the fuel leaving the high pressure outlet to the supply port and a second portion of the fuel leaving the high pressure outlet to the pumping means whereby fuel is delivered to the engine from the reservoir through the supply port and fuel is entrained into the reservoir by means of the fuel passing through the pumping means.

In accordance with other aspects of the invention, the apparatus further includes:

(a) a return port leading to the reservoir for receiving fuel returning from the engine; and

(b) a valve associated with the return port and the high pressure pump, the valve being open when the pump is operating so that fuel can pass between the engine and the reservoir and the valve being closed when the pump is not operating so that fuel cannot pass between the engine and the reservoir.

In accordance with certain preferred embodiments of the invention, the valve controlling flow through the return port includes a diaphragm and a spring, the spring moving the diaphragm to a position where the valve is closed, and the diaphragm being connected to the high pressure outlet of the pump so that when the pump is operating, fuel from the high pressure outlet moves the diaphragm against the force of the spring to a position where the valve is open.

In accordance with additional aspects of the invention, apparatus is provided for supplying fuel to an engine which comprises:

(a) a supply manifold for receiving fuel to be supplied to the engine;

(b) a return manifold for receiving fuel returning from the engine;

(c) a first fuel tank;

(d) a first pump associated with the first fuel tank and having an inlet connected to the first fuel tank and a high pressure outlet;

(e) first means for delivering fuel from the high pressure outlet of the first pump to the supply manifold;

(f) second means for delivering fuel from the return manifold to the first fuel tank;

(g) first and second hydraulically-operated valves associated with the first and second means, respectively, and with the first pump, each of the valves being open when the first pump is operating so that fuel can pass through the first and second means and being closed when the first pump is not operating so that fuel cannot pass through the first and second means;

(h) a second fuel tank;

(i) a second pump associated with the second fuel tank and having an inlet connected to the second fuel tank and a high pressure outlet;

(j) third means for delivering fuel from the high pressure outlet of the second pump to the supply manifold;

(k) fourth means for delivering fuel from the return manifold to the second fuel tank;

(l) third and fourth hydraulically-operated valves associated with the third and fourth means, respectively, and with the second pump, each of the valves being open when the second pump is operating so that fuel can pass through the third and fourth means and being closed when the second pump is not operating so that fuel cannot pass through the third and fourth means; and

(m) means for selectively activating the first or second pump whereby when the first pump is activated fuel passes from the first tank to the engine and back to the first tank and when the second pump is activated fuel passes from the second tank to the engine and back to the second tank.

The accompanying drawings, which are incorporated in and constitute part of the specification, illustrate the preferred embodiments of the invention, and together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram illustrating the application of the present invention to a fuel-injected engine supplied by fuel from two fuel tanks. The unnumbered arrows in this figure and in FIGS. 2-9 indicate the direction of fuel flow through the various components of the apparatus.

FIGS. 2-9 illustrate a particularly preferred construction for the apparatus of the present invention, wherein:

FIG. 2 is a perspective view showing the apparatus mounted in a fuel tank.

FIG. 3 is an exploded view of the components housed within the reservoir portion of the apparatus.

FIG. 4 is a top of view of the reservoir portion of the apparatus.

FIG. 5 is a side view of the components housed within the reservoir portion of the apparatus.

FIG. 6 is a cross-sectional view along lines 6—6 in FIG. 4 showing the jet pump, check valve, and shuttle valve components of the apparatus.

FIG. 7 is a cross-sectional view along lines 7—7 in FIG. 4 showing the internal structure of the jet pump.

FIG. 8 is a cross-sectional view along lines 8—8 in FIG. 4 illustrating the routing of fuel from the high pressure outlet of the high pressure pump to the jet pump, check valve, and shuttle valve.

FIG. 9 is a perspective view from below showing the construction of the bottom portion of the jet pump.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. 1 a schematic diagram illustrating the application of the present invention to a fuel-injected engine which is supplied with fuel from two fuel tanks. Although the invention will be described in connection with such a two fuel tank embodiment, it is to be understood that this description is for purposes of illustration only and that various features of the invention can be practiced with a single fuel tank. Similarly, the invention can be used with engines which are supplied with fuel from more than two fuel tanks.

As indicated in FIG. 1, reservoirs 10 and 10' are mounted in fuel tanks 1 and 2, respectively, the location of the reservoir being preferably at or near the bottom of the fuel tank. Each reservoir includes a top opening 12 and a bottom opening 14, each of which connect the interior of the reservoir to the interior of its respective main tank. Below each bottom opening is mounted a filter 18, which filters the fuel entering the reservoir from the main tank through the bottom opening. Above each bottom opening is a one-way check valve 22, which prevents fuel from passing out of the reservoir into the main tank through the bottom opening. Each reservoir also includes a supply port 32, through which fuel is supplied to the engine, and a return port 36, through which fuel returns to the reservoir from the engine.

Within each reservoir is a high pressure pump 26, a jet pump 30, a shuttle valve 34, and a check valve 38 The high pressure pump is electrically-operated and is of standard design for use with fuel-injected engines. It includes an inlet 42 and a high pressure outlet 46. The inlet is preferably covered by a filter 50.

Jet pump 30 includes nozzle 54 and venturi tube 58. Flow of fuel out of nozzle 54 and through venturi tube 58 causes a reduction in pressure in the region of opening 14 relative to the pressure in the main fuel tank, which in turn, causes fuel to be entrained into the reservoir from the fuel tank.

Shuttle valve 34, which controls the flow of fuel returning from the engine through return port 36, has an

open position in which fuel can pass through the valve and a closed position in which fuel cannot pass through the valve. The valve includes diaphragm 62, piston 66, spring 70, and O-ring 74. Spring 70 urges the valve into its closed position wherein O-ring 74 is in contact with surface 78 formed in the valve body. As discussed below, when high pressure pump 26 is operating, fuel from the high pressure outlet 46 of the pump moves diaphragm 62 against the force of spring 70. This movement of the diaphragm opens the valve by moving O-ring 74 out of engagement with surface 78.

Check valve 38 also has an open position in which fuel can pass through the valve and a closed position in which fuel cannot pass through the valve. This valve allows fuel to flow out of the reservoir through supply port 32. The valve includes piston 82, spring 86, and O-ring 90. Spring 86 urges the valve into its closed position wherein O-ring 90 is in contact with surface 94 formed in the valve body. When high pressure pump 26 is operating, the valve is opened by fuel from high pressure outlet 46 moving piston 82 so as to bring O-ring 90 out of contact with surface 94.

As shown in FIG. 1, the output of high pressure pump 26 is routed to each of jet pump 30, shuttle valve 34, and check valve 38 by lines 98, 102, and 106, respectively. Accordingly, when the pump is in operation, both valves will be open, fuel will be leaving the reservoir through supply port 32 and returning through return port 36, and the jet pump will be entraining fuel into the reservoir. On the other hand, when the pump is not in operation, both valves will be closed, fuel will neither be leaving nor returning to the reservoir, and the jet pump will not be filling the reservoir with fuel. Fuel, however, will not leave the reservoir because of check valve 22.

Jet pump 30 is preferably sized so that it entrains more fuel into the reservoir than leaves the reservoir through supply port 32 under maximum fuel consumption conditions. For example, it has been found convenient to select a nozzle 54 which, for the operating parameters of the engine, allows approximately one unit of fuel to pass through the jet pump for every four units of fuel which pass out of supply port 32, and to size venturi tube 58 so that approximately five units of fuel are entrained through opening 14 for every unit of fuel passing through nozzle 54. For this combination, approximately six units of fuel enter the reservoir for every four units of fuel leaving the reservoir through supply port 32.

This extra entrainment provides a safety margin to insure that there is always fuel at inlet 42 of high pressure pump 26. The return of fuel to the reservoir through return port 36 and shuttle valve 34 also helps insure that there is always fuel at the inlet to the pump, especially under low fuel conditions where there may not be fuel in the main tank in the region of opening 14.

As mentioned above, recycling of returning fuel is, in general, undesirable since it leads to hot fuel problems. To avoid these problems, outlet 110 of shuttle valve 34 is oriented horizontally and is set at a level above the level of inlet 42 to high pressure pump 26. Since the returning fuel is warmer than the fuel being entrained into the bottom of the reservoir by jet pump 30, there is, in general, no thermal gradient tending to move the returning fuel below the level of outlet 110. Moreover, for a jet pump sized so that more fuel is pumped into the reservoir by the jet pump than is pumped out of the reservoir by the high pressure pump, there will be a net flow of fuel from the bottom to the top of the reservoir and out of top opening 12. Such a flow will carry the warm, returning fuel out of the reservoir into the main tank and away from the inlet to the high pressure pump. Thus, in accordance with the invention, warm fuel will only reach the inlet to the high pressure pump when fuel is not present at the inlet 14 to reservoir 10, so that the only fuel available for pumping to the engine is the unused fuel returning from the engine, as may occur, for example, under shifting fuel or low fuel conditions.

As mentioned above, the present invention can be used for engines having only a single fuel tank. In such a case, one of the reservoirs shown in FIG. 1 is mounted in the fuel tank, supply port 32 is connected directly to intake 114 to injectors 116, and return port 36 is connected directly to the output 118 of regulator 120. As is standard in the art, regulator 120 provides a constant pressure head at injectors 116. A typical setting for regulator 120 is on the order of 39 pounds per square inch at idle and 30 pounds per square inch at open throttle.

When applied to single fuel tank engines, the present invention provides a variety of advantages and improvements over the prior art, including: (1) only one high pressure pump is employed, as opposed to both a high pressure pump and a low pressure pump; (2) cool fuel is supplied to the inlet of the high pressure pump even under conditions of high fuel consumption by the engine: (3) returning warm fuel is available to the pump under low fuel or fuel shifting conditions, but is isolated from the inlet to the pump under normal conditions; (4) both the supply port and return port open automatically when the high pressure pump is on and close automatically when it is off; and (5) the high pressure pump, jet pump, and the valves controlling flow to and from the engine can readily be mounted within the reservoir, thus providing a single unit which lowers assembly, replacement and repair costs.

When applied to engines having multiple fuel tanks, supply port 32 of each reservoir is connected to a common supply manifold 122, which in turn, is connected to intake 114 to injectors 116. Similarly, return ports 36 are connected to a common return manifold 124 which is connected to output 118 of regulator 120. Because of the automatic opening and closing of check valves 38 and shuttle valves 34, switching between tanks, in accordance with the invention, simply involves turning off the high pressure pump in the tank which no longer is to be used and turning on the high pressure pump in the tank which is to be used, the switching of the routing of fuel to and from the active tank being taken care of automatically by the common supply and return manifolds and by the automatic opening and closing of the various check and supply valves.

Manifolds 122 and 124 need not have any particular configuration and can simply involve connecting all of the supply ports to intake 114 and all of the return ports to output 118. Switching between high pressure pumps can be done by conventional means known in the art, such as through the use of a single pole, double throw switch mounted in a convenient location.

Turning now to FIGS. 2-9, these figures show a particularly preferred construction for the apparatus of the present invention. As shown in FIG. 2, reservoir 10 is mounted within fuel tank 126 by means of mounting plate 129 which carries supply port 32 and return port 36. Mounting plate 129 is connected to reservoir 10 by stiffening rod 128. Supply port 32 and return port 36 are

connected to the reservoir by flexible hoses 130 and 132, respectively, which lead to supply nozzle 134 and return nozzle 136, respectively (see FIG. 3). The lengths of stiffening rod 128 and flexible hoses 130 and 132 are selected so that when mounting plate 129 is connected to fuel tank 126, filter 18, which is attached to the bottom of the reservoir, is located on or just above the bottom of the tank. Rather than using nozzles 134 and 136, and hoses 130 and 132, ports 32 and 36 can be connected directly to reservoir 10 using, for example, grommets at the junction of these ports with the reservoir. The reservoir includes opening 131 at its top to allow excess fuel which is pumped into the reservoir by the jet pump to escape (see FIGS. 3 and 4.

As shown most clearly in FIGS. 3 and 5, reservoir 10 is composed of reservoir can 138, main housing 140, and shuttle valve housing 142. Within the reservoir are located high pressure pump 26, shuttle valve 34, check valve 38, and jet pump 30 formed in jet block 144. Stiffening rod 128 passes through the reservoir and is connected to main housing 140 and jet block 144 by grommets 146 and 148, respectively.

High pressure pump 26 is mounted between main housing 140 and opening 154 in jet block 144. Inlet 42 to the high pressure pump is covered by filter 50. The pump's high pressure outlet 46 leads into main housing 140, the housing and the pump being sealed by O-ring 150. The high pressure pump includes spade lugs 152 which are connected to a suitable wiring harness (not shown) through which the pump is energized.

As can best be seen in FIG. 8, main housing 140 includes chamber 156 which receives the output from the high pressure outlet 46 of high pressure pump 26. Chamber 156, in turn, is connected to passage 158 and to chambers 160 and 162. Chamber 162 receives check valve 38, orifice 158 is connected to shuttle valve 34, and chamber 160 is connected to jet block 144 by connecting tube 164, O-ring 166 being used to form a seal between chamber 160 and connecting tube 164 (see FIG. 7). By means of these interconnected passageways in main housing 140, the output of the high pressure pump is routed to the check valve, the shuttle valve, and the jet pump.

As discussed above in connection with FIG. 1, check valve 38 includes piston 82, spring 86, and O-ring 90, which mates with surface 94; shuttle valve 34 includes moveable diaphragm 2, piston 66, spring 70, and O-ring 74 which mates with surface 78; and jet pump 30 includes nozzle 54 and venturi tube 58. Check valve 38 can be conveniently set to open at a pressure of approximately 4 pounds per square inch, while shuttle valve 34 can be set to open at approximately fifteen pounds per square inch. The fifteen pounds per square inch value for the opening of the shuttle valve allows this valve to function as a means for relieving pressure within the fuel injection system which may build up when the engine is not in use, e.g., through heating of the injection manifold by residual engine heat.

As shown in FIG. 7, jet pump 30 preferably includes a filter 168 for filtering the fuel entering nozzle 54, the filter and nozzle being secured within jet block 144 by support 170. As shown in FIG. 9, jet block 144 includes baffles 172 whereby the fuel leaving the jet pump is isolated from the region of opening 154 which receives inlet 42 to high pressure pump 26. As also shown in that figure, the output of the jet pump is located diametrically opposite from the inlet to the high pressure pump and the output is aimed away from the inlet. In this way, the inlet to the high pressure pump sits in a relatively calm pool of fuel and is uneffected by the turbulence and, in some cases, frothing which results from the operation of the jet pump when entraining air.

As also shown in FIG. 9, jet block 144 includes projections 176 for retaining check valve 22 over opening 14 (see also FIG. 7). The inward surfaces 174 of these projections are tapered so that the check valve will not catch on the projections during use.

The following dimensions for nozzle 54 and venturi 58 have been found suitable for use with fuel-injected automobile engines, wherein the operating pressure of the engine, as set by regulator 120, is on the order of 40 pounds per square inch and wherein high pressure pump 26 produces a total flow of about 100 liters/hour when operating through such a regulator: diameter of nozzle orifice—approximately 0.023 inches: diameter of venturi tube—approximately 0.2 inches: length of venturi tube—approximately 1.0 inch: taper angle of bell mouth inlet 178 to venturi tube—approximately 5°; taper angle of flared outlet 180 from venturi tube—approximately 13°. Venturi tube 58, inlet 178 and outlet 180 are preferably formed with smooth surfaces to avoid generating excess turbulence in the fuel entrained by the jet pump.

Jet pumps formed with smooth surfaces and having the foregoing dimensions, when connected to a 100 liter per hour high pressure pump and to a fuel-injected automobile engine operating at approximately 40 pounds per square inch, have been found to have a flow rate through the jet pump of approximately 20 liters per hour and to entrain approximately 5 liters of fuel for every 1 liter of fuel passing through the jet pump.

The components making up the fuel pump assembly of the present invention can be made of standard materials used in the automotive industry. For example, nozzle 54 can be made of stainless steel, diaphragm 62 can be made of fluorosilicone, and reservoir can 138, main housing 140, shuttle valve housing 142, and jet block 144 can be made of nylon or polyester.

Although specific embodiments of the invention have been described and illustrated, it is to be understood that modifications can be made without departing from the invention's spirit and scope. For example, valves and pumps having constructions other than those illustrated in the figures can be used in the practice of the invention. Similarly, the components of the invention can be arranged relative to one another in a variety of configurations other than those shown.

What is claimed is:

1. Apparatus for pumping fuel from a fuel tank to an engine comprising:

(a) a supply port for carrying fuel from the apparatus to the engine;

(b) a pump having an inlet connected to the fuel tank and a high pressure outlet;

(c) means for routing fuel leaving the high pressure outlet to the supply port;

(d) a return port connected to the fuel tank for receiving fuel returning from the engine; and

(e) a valve associated with the return port and including a diaphragm and a spring, said diaphragm having a first position in which the valve is closed so that fuel cannot pass between the engine and the fuel tank through the return port, and a second position in which the valve is open so that fuel can pass between the engine and the fuel tank through

the return port, said spring urging the diaphragm towards its first position; and

(f) means for connecting the high pressure outlet of the pump to the valve so that when the pump is operating, fuel from the high pressure outlet moves the diaphragm to its second position against the force of the spring.

2. Apparatus for pumping fuel from a fuel tank to an engine comprising:

(a) a supply port for carrying fuel from the apparatus to the engine;

(b) a fuel reservoir which includes an opening for connecting the interior of the reservoir to the interior of the fuel tank;

(c) means for mounting the reservoir in the fuel tank so as to locate the opening of the reservoir in the region of the bottom of the fuel tank;

(d) pumping means for pumping fuel into the reservoir, said means being located within the reservoir in the region of the opening and including a nozzle and a venturi tube in alignment with the nozzle, the passage of fuel out of the nozzle and through the venturi tube causing fuel to be entrained through the opening into the interior of the reservoir;

(e) a high pressure pump having an inlet connected to the interior of the reservoir and an output of high pressure fuel; and

(f) means for routing a first portion of the output of high pressure fuel to the supply port and a second portion of the output of high pressure fuel to the pumping means whereby fuel is delivered to the engine from the reservoir through the supply port and fuel is entrained into the reservoir by means of the fuel passing through the pumping means.

3. The apparatus of claim 1 further including:

(a) a return port leading to the reservoir or receiving fuel returning from the engine; and

(b) a valve associated with the return port, and the high pressure pump, the valve being open when the pump is operating so that fuel can pass between the engine and the reservoir and the valve being closed when the pump is not operating so that fuel cannot pass between the engine and the reservoir.

4. The apparatus of claim 3 wherein the valve includes a diaphragm and a spring, said diaphragm having a first position in which the valve is closed and a second position in which the valve is open, said spring urging the diaphragm towards its first position, and wherein the apparatus includes means for connecting a portion of the output of high pressure fuel to the valve so that when the pump is operating, said portion can move the diaphragm to its second position against the force of the spring.

5. The apparatus of claim 3 wherein the inlet to the high pressure pump is connected to the reservoir at a level below the level at which fuel is returned to the reservoir from the engine through the return port.

6. The apparatus of claim 3 wherein the fuel returning to the reservoir from the engine through the return port enters the reservoir horizontally.

7. The apparatus of claim 2 wherein the outlet from the pumping means is separated from the inlet to the high pressure pump by a baffle.

8. The apparatus of claim 2 wherein the opening is located at the bottom of the reservoir and wherein the first portion of the output of high pressure fuel is less than the sum of the second portion plus the amount of fuel entrained into the reservoir by the pumping means so that more fuel enters the reservoir through the opening than leaves the reservoir through the supply port thereby creating a net flow of fuel from the bottom to the top of the reservoir.

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US005452701A

United States Patent [19]

Tuckey

[11] Patent Number: 5,452,701

[45] Date of Patent: Sep. 26, 1995

[54] **TURBINE FUEL PUMP WITH FUEL JET**

[75] Inventor: **Charles H. Tuckey**, Cass City, Mich.

[73] Assignee: **Walbro Corporation**, Cass City, Mich.

[21] Appl. No.: **247,560**

[22] Filed: **May 23, 1994**

[51] Int. Cl.[6] **F02M 37/04**

[52] U.S. Cl. **123/509**; 417/83

[58] Field of Search 123/509, 510, 123/514; 417/80, 83, 84, 423.3

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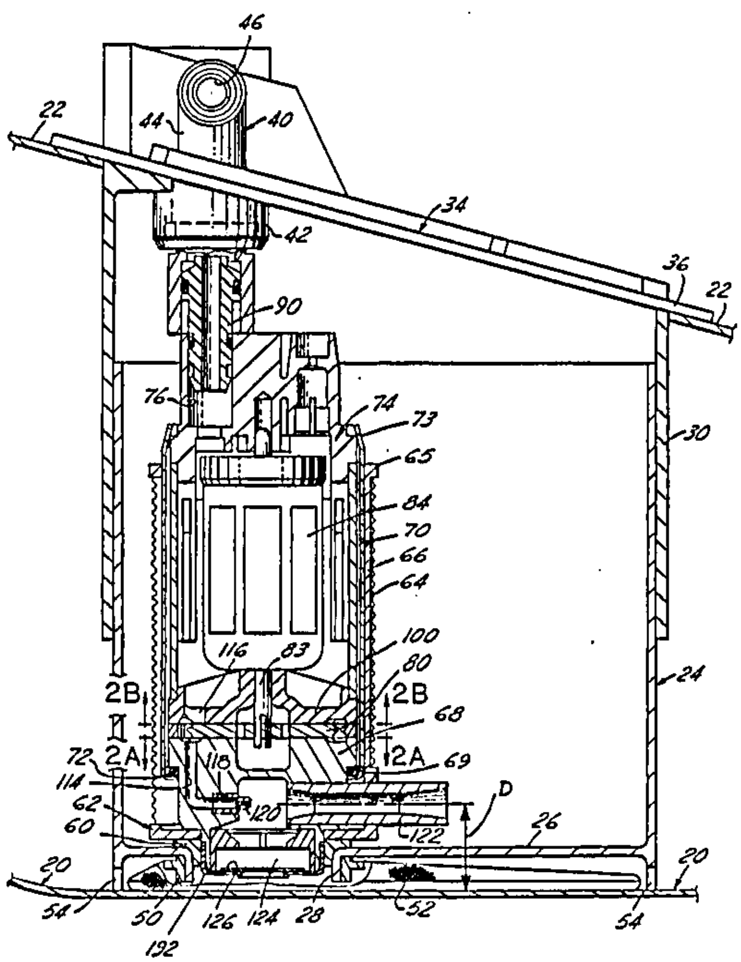
Primary Examiner—Thomas N. Moulis
Attorney, Agent, or Firm—Barnes, Kisselle, Raisch, Choate, Whittemore & Hulbert

[57] **ABSTRACT**

An electrically operated fuel pump for automotive vehicles which utilizes a turbine pump rotor operating in an annular pumping channel having circumferentially spaced inlet and outlet ports. The pumping channel has opposed sides with a circumferential array of radially curved grooves axially opposed to the periphery of the impeller and extending radially inwardly from the impeller vanes. The pump has a main outlet leading to the engine to be supplied with fuel. A secondary outlet leads to a fuel jet positioned to direct fuel into a venturi passage to draw fuel from a pump inlet and discharge it into a reservoir in a main fuel tank, the pump being located in the reservoir. A biased valve in the secondary outlet opens when the pump outlet pressure reaches a predetermined pressure to insure adequate fuel flow to the engine upon cold start conditions before fuel is drawn by the jet and venturi and delivered to the reservoir.

15 Claims, 2 Drawing Sheets



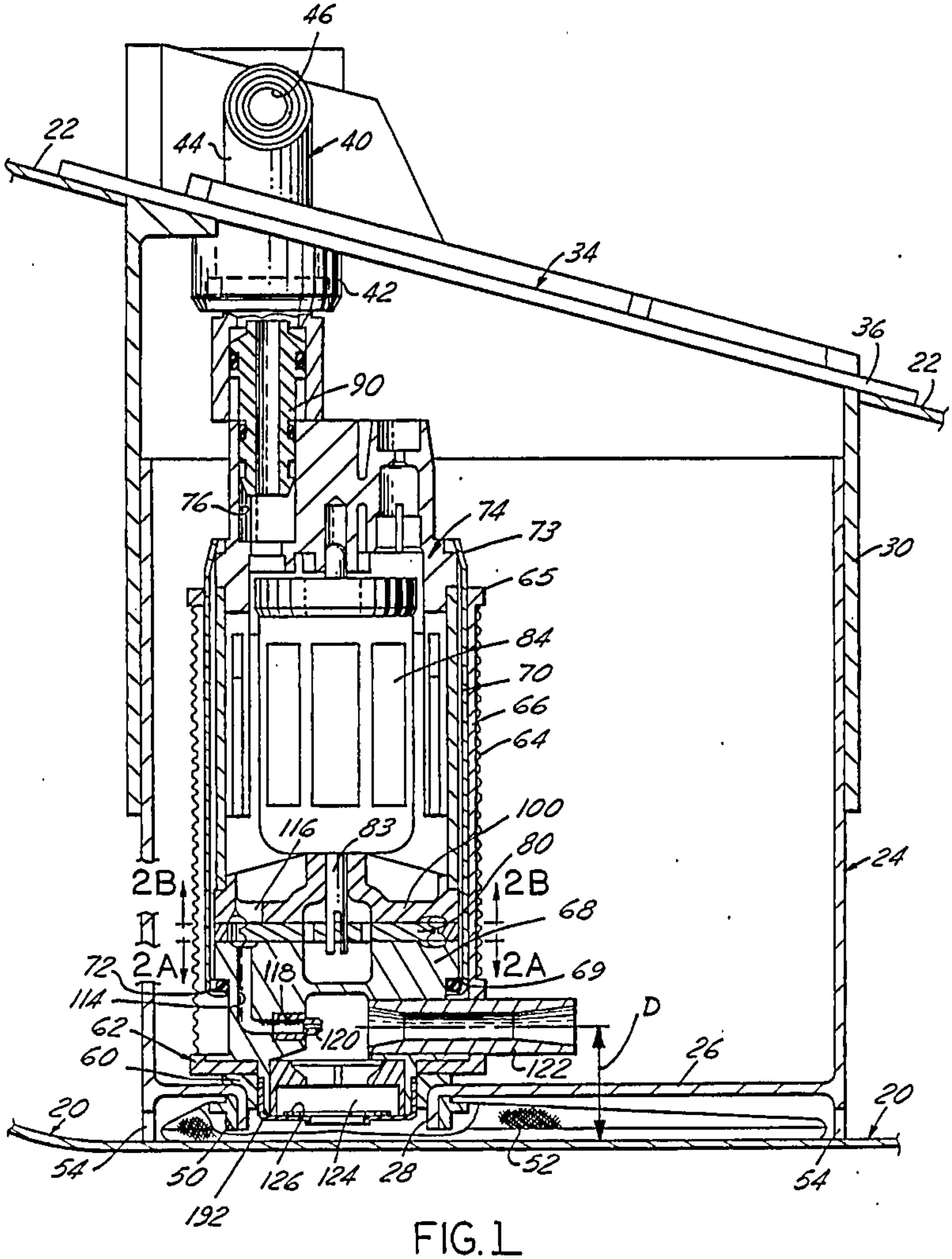

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FIG. 1

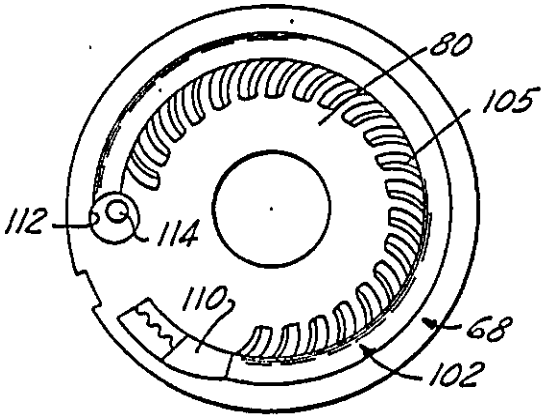

FIG.2A

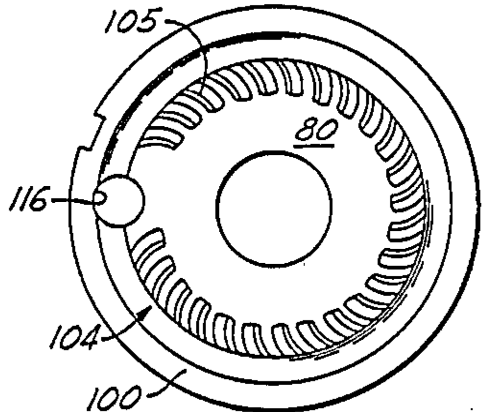

FIG.2B

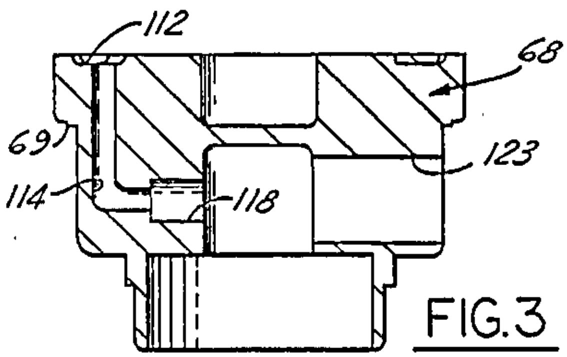

FIG.3

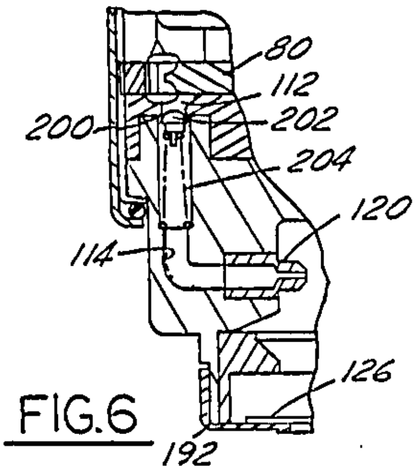

FIG.6

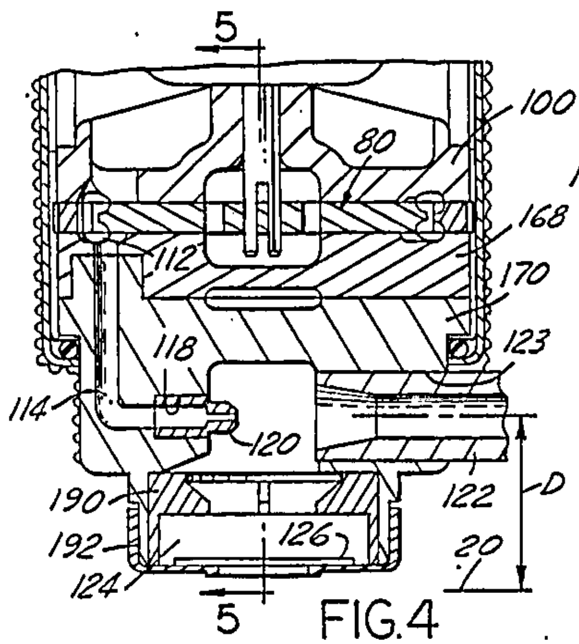

FIG.4

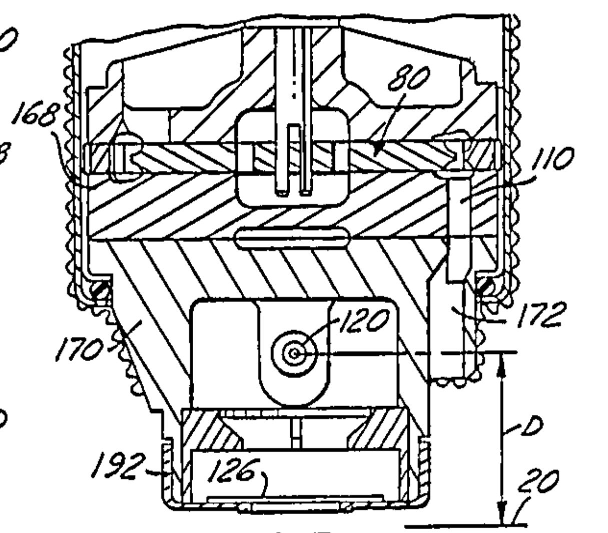

FIG.5

TURBINE FUEL PUMP WITH FUEL JET

FIELD OF INVENTION

A fuel system for internal combustion engines with a main fuel tank, an in-tank reservoir and a turbine pump and a side jet.

BACKGROUND OF INVENTION

In the furnishing of fuel to an engine, it has been the practice to use positive displacement pumps to pick up fuel from a tank and deliver it to the fuel rail and fuel injectors of an engine. Vane pumps and gear rotor pumps have been used and these pumps generate substantial pull at the inlet as well as a positive outlet pressure. Side fuel jets have been associated with these pumps to bleed off some of the pump outlet and direct it to a combined jet and venturi. This venturi will pull fuel from the main fuel tank and direct it to an in-tank reservoir for holding reserve fuel. In some instances, a fuel system would have a return line controlled by a pressure regulator to direct excessive fuel to an in-tank reservoir. More recently, with the advent of pressure responsive pumps to control pump speed, the return line was not necessary. However, it was still important to get fuel into the reservoir and the side jet venturi became useful to do this. See jet disclosure in U.S. Pat. No. 4,860,714 issued Aug. 29, 1989.

The very nature of positive displacement pumps resulted in a certain noise factor when operating. Since these pumps are located in the main fuel tank at the rear of a vehicle, the noise could be transmitted to the passenger compartment. A new type of pump became useful in the form of a rotary turbine pump. The rotor, having vanes at the periphery, rotates in an annular chamber, and fuel is pulled in at an inlet section and discharged at a circumferentially spaced outlet area.

SUMMARY OF THE INVENTION

One disadvantage of the turbine pump has been that, upon cold start, there is low voltage applied to the pump and low output pressure from the pump. When used with a side jet venturi, as was customary with the positive displacement pumps, the fuel delivery to the engine was not up to a desirable level. It is an object of this invention to provide a time delay period upon cold start-up, which will block flow to the side jet venturi for a predetermined time, thus allowing full pump delivery of an adequate fuel supply to the engine until voltage has reached a normal operating level.

Another object of the invention lies in the design of the turbine pump housing and side jet venturi to insure restoration of fuel delivery after a main fuel tank and reservoir have been drained of fuel; in other words, the vehicle has run out of gas. Usually, when this happens, the operator gets a small amount of gas at a station and pours it into the gas tank. This provides a low level of fuel in the tank, perhaps ¾". It is essential that a turbine pump be able to pick-up this low level of fuel enough to start the engine and get to a gas station. Thus, the invention is directed to a low profile pump base which locates the pump inlets close to the tank base.

A turbine pump, located in an in-tank reservoir of a vehicle fuel tank, has a main pump outlet for the fuel rail of an engine. A side-jet venturi is associated with the main pump and the jet receives fuel under pressure from the turbine pump through a shunt passage. A biased valve in the shunt passage blocks flow from the turbine pump until the pump outlet reaches a predetermined pressure, thus insuring full pump outlet flow to the engine until such pressure is reached. The base of the pump and the pump inlets are designed with a low profile to insure fuel pick-up with a low fuel level in the main tank.

BRIEF DESCRIPTION OF THE DRAWINGS

The above recited objects of the invention and other objects, features and advantages of the invention will be apparent in the following detailed description of the preferred embodiment and best mode, appended claims, and accompanying drawings in which:

FIG. 1 is a vertical sectional view of a fuel tank and in-tank reservoir with a turbine pump and side jet.

FIG. 2A is a section on line 2A—2A of FIG. 1 illustrating a lower pump plate.

FIG. 2B is a mirror section of FIG. 2A on line 2B—2B of FIG. 1 illustrating the upper pump plate.

FIG. 3 is a section of the pump base.

FIG. 4 is an enlarged sectional view of the pump base formed of two elements.

FIG. 5 is a section of the pump base, rotated from the showing in FIGS. 1 and 4, to show the turbine pump inlet.

FIG. 6 illustrates a sectional view of the pump base of FIG. 1 with a delay check valve in the jet passage.

DETAILED DESCRIPTION

With reference to the drawings, FIG. 1 shows an elevation partially in section, of a main fuel tank having a bottom wall 20 and a top wall 22. An in-tank reservoir is formed of a base housing 24 resting on the bottom 20 and having a raised bottom wall 26 with a flanged opening 28. A top housing 30 has an angled closure 34 with an extending flange 36 and has a telescoping relation with bottom wall 24. The top closure 34 has an integral outlet fixture 40 with a depending portion 42 and an uptanding portion 44. A pump outlet passage in this fixture terminates in an outlet port 46.

The telescoping housings 24 and 34 form what is termed an "in-tank" reservoir and within this reservoir is an electrically powered turbine pump. U.S. Pat. No. 5,257,916 of C. H. Tuckey, which issued Nov. 2, 1993, illustrates and describes a turbine pump.

In FIG. 1, a filter fastening grommet 50 secures a flat fuel filter 52 on the flange around opening 28. The filter lies on the tank bottom below the raised bottom wall 26 of the housing 24. Openings 54 in the bottom of housing 24 admit fuel to the filter 52.

A sealing grommet 60 rests on the periphery of the flanged opening 28 and this grommet supports a base ring 62 of a jacket filter sleeve 64, which has a top ring 65. Vertical connectors, one of which 66 is shown, extend between the base ring 62 and the top ring 65. The filter jacket sleeve 64 extends between the base ring 62 and the top ring 65 and serves to filter fuel passing from the reservoir into the pump inlet. A pump base housing 68 (shown also in FIGS. 1 and 3) rests on the inner periphery of ring 62 and has an annular shoulder 69. The pump has a sealing jacket 70 spun in around an O-ring 72 at shoulder 69 on base 68, and sealed at the top 73 against a pump outlet housing 74. The pump outlet housing 74 has a pump outlet pas sage 76.

The pump within the jacket 70 has a turbine element 80 driven by a shaft 83 of an armature 84. Reference is made to U.S. Pat. No. 5,257,916 issued Nov. 2, 1993 for a full

disclosure of a pump of the type shown in FIG. 1. A double ended sealing connector **90** inserts into pump outlet **76** at one end and into outlet fixture **40** at depending portion **42**.

The turbine element **80** rotates with its periphery moving in an annular pumping channel formed on one side by a top housing **100** and on the other side by an annular channel on the top surface of pump base housing **68**. FIGS. 2A and 2B, taken on lines 2A—2A and 2B—2B of FIG. 1, show these respective channels **102** in housing **68** and **104** in housing **100**. In each channel, a circumferential array of generally radially oriented grooves **105** are formed extending radially inward respectively from pumping channels **102** and **104** (FIGS. 2A and 2B). An inlet port **110** is provided in base **68** and a pump outlet port **112** in this base opens to a side jet by-pass passage **114** (FIG. 3). In top housing **100**, a main pump outlet passage **116** opens to the armature chamber and to the main pump outlet **76**.

In base housing **68**, the passage **114** (FIG. 4) leads to an opening **118**, in which is located a jet orifice **120** which discharges into a venturi tube **122** mounted in bore **123**. A pump inlet chamber **124** has a one-way foot valve **126** which admits fuel from the filter at the base of the tank **24** to the venturi tube **122**. The jet **120** and the venturi tube **122** are co-axial and parallel to the base of the fuel tank.

In FIGS. 4 and 5, the base housing **68** of the pump, shown in FIG. 3, is formed of two plates **168** and **170**. Otherwise, the effective base is the same. A pump inlet **110** aligns with an inlet passage **172** shown in FIG. 5 but this passage is the same in the one-piece base **68**. The foot valve assembly is formed of a ring **190** retained by a flanged ring **192**.

In FIG. 6, a modified structure is illustrated in which the jet fuel outlet **112** is formed with a valve seat **200**. A domed check valve **202**, backed by a coil spring **204**, is positioned against the seat **200**. The spring **204** is calibrated to a predetermined value so that it opens to furnish pump outlet fuel to the jet **120** only when that value is reached. This insures that, under conditions of low voltage and cold start-up, the fuel pump outlet fuel will reach the engine before the side jet starts to operate.

As shown in FIG. 1, the coaxial centerline of the venturi **122** as well as the jet **120** is located above the tank bottom **20** at a dimension D which can be about 0.650 of an inch or lower. The entire base construction of the pump assembly is designed to provide this low dimension D of the pump inlet **172** (FIG. 5). When a tank is almost completely emptied for lack of gasoline refill, the operator usually will obtain a gallon of gas at a station and empty it into the gas tank. This will provide a level in the bottom of the tank of about ¾" to 1". Thus, it is essential that fuel be available to the pump inlet to start the engine and enable the vehicle to reach a source of tank refill.

OPERATION

With the pump and in-tank reservoir assembly described, a turbine pump has a rotor operating in a channel at the periphery. The turbine pump is also associated with a side-jet outlet in which fuel from the turbine is directed to a main fuel outlet leading to the engine and a portion of the fuel is directed to the side jet which delivers to a venturi. The jet action pulls fuel from the main tank and delivers it to the reservoir.

Under low voltage-cold start conditions, the turbine pump **80** operating within the opposed channels in body **68** and top housing **100** will provide sufficient fuel to supply the engine as well as the side jet **120**. This is true if each of the channels

have the full circumferential array of radial grooves as viewed in FIGS. 2A and 2B.

If the turbine pump does not have the full circumferential array of radial grooves, as illustrated in U.S. Pat. No. 5,257,916, it may be desirable to interpose a pressure delay valve **202** between the pump outlet and the side jet as illustrated in FIG. 6. With this arrangement, the full fuel discharge of the pump goes directly to the engine. When the pressure reaches a predetermined value to overcome the spring **204** in FIG. 6, the fuel outlet from the pump will flow to the engine as well as to the side jet **120** and start filling the reservoir.

The filter jacket sleeve **64** surrounds the pump inlet **172** in FIG. 5 and filters fuel as it passes from the reservoir to the pump inlet.

What is claimed is:

1. An electric-motor fuel pump for installation in a vehicle fuel tank that comprises,

a housing including a main fuel outlet and a main fuel inlet opening to the exterior of said housing immediately adjacent the bottom thereof and immediately adjacent the bottom of the fuel tank when installed therein,

an electric motor in said housing and including a rotor and means for applying electrical energy to said motor to rotate said rotor in said housing, and

a turbine pump in said housing and including an impeller coupled to said rotor for co-rotation therewith and having a periphery with a circumferential array of vanes, an arcuate pumping channel surrounding said impeller periphery and communicating with said main fuel outlet and a turbine pump fuel inlet coupled with said pumping channel and communicating with the exterior of said housing immediately adjacent the bottom thereof and being located immediately adjacent the bottom of the fuel tank when installed therein,

said pump having a base housing which includes the main fuel inlet, a secondary fuel outlet in said base housing in communication with said pumping channel, a jet in said secondary fuel outlet, a venturi passage having an outlet end opening to the exterior of said housing and an inlet end axially opposed to said jet, said venturi passage being in communication with said main fuel inlet, whereby turbine pump outlet fuel in said secondary outlet discharging into said jet draws fuel into said venturi passage through said main inlet and discharges fuel from said venturi passage outlet end.

2. A fuel pump as defined in claim 1 in which there is provided a main fuel tank for a vehicle, a reservoir within said main fuel tank, said fuel pump being mounted on said base housing in said reservoir, said outlet end of said venturi passage being open to said reservoir, said turbine pump having a primary fuel outlet in communication with the interior of said reservoir, whereby fuel from said secondary outlet of said turbine pump passes through said jet into said venturi passage and draws fuel from said main inlet and moves it into said reservoir.

3. A fuel pump as defined in claim 1 in which said secondary fuel outlet in said base comprises an L-shaped passage having a first end at said pumping channel and a second end at said jet, said venturi passage in said base being axially aligned with said jet, said inlet end of said venturi passage being located above said main fuel inlet whereby fuel from said jet discharges into said inlet end of said

venturi passage to draw fuel from said main inlet and move it through said venturi.

4. A fuel pump assembly as defined in claim 3 in which a foot valve in said base provides a one-way passage into said main fuel inlet.

5. A fuel pump as defined in claim 1 in which the turbine pump also comprises a circumferential array of generally radially oriented grooves on each side of said impeller, communicating with said pumping channel and extending generally radially inward of the periphery of said impeller.

6. An electric-motor fuel pump for installation in a fuel tank that comprises,

a housing including a main fuel inlet and a fuel outlet,

an electric motor including a rotor and means for applying electrical energy to said motor to rotate said rotor in said housing, and

a turbine pump in said housing and including an impeller coupled to said rotor for co-rotation therewith and having a periphery with circumferential array of vanes, an arcuate pumping channel surrounding said impeller periphery and communicating with said fuel outlet and a turbine pump inlet coupled to said pumping channel and opening to the exterior of said housing immediately adjacent the bottom of said housing,

said fuel pump having a base housing in which is formed the main fuel inlet, a secondary fuel outlet including an outlet passage in said base housing in communication with said pumping channel, a jet located in said secondary outlet passage, a biased valve in said outlet passage biased against flow from said pumping channel, a venturi passage in said base housing having an outlet end, and having an inlet end axially opposed to said jet, said venturi passage being in communication with said main fuel inlet, and means biasing said valve to allow flow to said outlet passage and said jet upon outlet pressure in said pumping channel reaching a predetermined value, whereby turbine pump outlet fuel in said secondary outlet passage discharging into said jet draws fuel into said venturi passage through said main fuel inlet and discharges fuel from said venturi passage outlet end.

7. A fuel pump assembly as defined in claim 6 in which said main fuel inlet is mounted in said base housing directly adjacent the bottom of said main fuel tank, and said jet and inlet end of said venturi passage are aligned substantially horizontally above said main fuel inlet, the axis of said jet and said venturi passage being positioned three quarters of an inch or less above the bottom of said main fuel tank.

8. A fuel pump as defined in claim 7 in which said base housing is comprised of a first pump channel plate positioned below said turbine pump impeller, and a second base plate subjacent said first plate having the secondary fuel outlet, said jet and said venturi passage formed therein.

9. A fuel pump assembly as defined in claim 7 in which a sock filter is located on the bottom of a fuel tank and having an outlet opening to said main fuel inlet.

10. A fuel pump assembly as defined in claim 9 in which said main fuel tank has a reservoir with a raised bottom wall above said sock filter, said bottom wall having an opening to receive and locate said pump base housing.

11. A fuel pump as defined in claim 6 in which said pump housing comprises a base inlet housing and a top outlet housing joined by a sealed encapsulating cylindrical shell, said main inlet being in said base housing, a cylindrical filter jacket surrounding said shell formed of fuel filter material and having a portion enclosing said turbine pump inlet in said base inlet housing to filter fuel flowing from said reservoir to said turbine pump inlet.

12. A fuel pump as defined in claim 6 in which the turbine pump also comprises a circumferential array of generally radially oriented grooves on each side of said impeller, communicating with said pumping channel and extending generally radially inward of the periphery of said impeller.

13. A fuel pump as defined in claim 6 in which said secondary fuel outlet in said base comprises an L-shaped passage having a first end at said pumping channel and a second end at said jet, said venturi passage in said base being axially aligned with said jet, said inlet end of said venturi passage being located above said main fuel inlet whereby fuel from said jet discharges into said inlet end of said venturi passage to draw fuel from said main inlet and move it through said venturi.

14. An electric motor fuel pump for installation in a vehicle fuel tank which comprises, a housing having a cylindrical shell, a first end cap received and carried by said shell adjacent one end thereof and having a fuel outlet, a second end cap carried by said shell adjacent the other end thereof and having a fuel inlet opening to the exterior of said housing immediately adjacent the bottom thereof and immediately adjacent the bottom of the fuel tank when the fuel pump is installed therein, an electric motor received in said housing and having a rotor journalled for rotation in said housing, a turbine pump in said housing and having an impeller coupled to said rotor for rotation therewith, an array of vanes circumferentially spaced apart about the periphery of said impeller, an arcuate pumping channel surrounding said impeller periphery, a first outlet coupled with said pumping channel and communicating with said main fuel outlet, a second outlet coupled with said pumping channel, an inlet coupled with said pumping channel and having an opening communicating with the exterior of said housing immediately adjacent the bottom thereof, and said inlet opening being located immediately adjacent the bottom of the fuel tank when the fuel pump is installed therein, a jet coupled to said secondary fuel outlet, and a venturi carried by said second cap and having an inlet end disposed generally axially downstream of said jet and communicating with said fuel inlet in said second end cap, and an outlet opening to the exterior of said housing immediately adjacent the bottom thereof and said outlet being located immediately adjacent the bottom of the fuel tank when the fuel pump is installed therein and spaced from said fuel inlet of said turbine pump.

15. A fuel pump assembly as defined in claim 14 wherein when said fuel pump is installed in a fuel tank, said opening of said inlet to said pump channel is within about 0.65 of an inch of the bottom of the tank.

* * * * *

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US006227819B1

(12) **United States Patent**
Gettel et al.

(10) **Patent No.: US 6,227,819 B1**
(45) **Date of Patent: May 8, 2001**

(54) **FUEL PUMPING ASSEMBLY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/594,141**

(22) Filed: **Jun. 14, 2000**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/527,722, filed on Mar. 17, 2000, which is a continuation-in-part of application No. 09/282,053, filed on Mar. 29, 1999.

(51) **Int. Cl.**^{7} **F04B 17/00**; F04B 35/04

(52) **U.S. Cl.** **417/423.1**; 415/55.1

(58) **Field of Search** 417/423.7, 423.12, 417/244, 423.3, 423.1, 44.2; 415/55.1, 55.6, 55.2; 123/514

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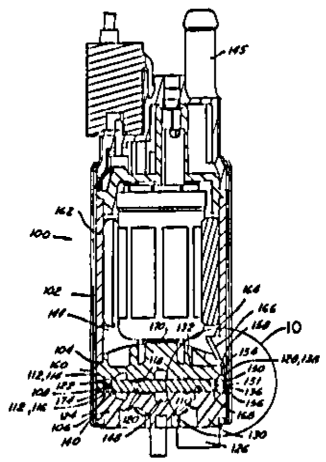
Assistant Examiner—Leonid Fastovsky
(74) *Attorney, Agent, or Firm*—Reising, Ethington, Barnes, Kisselle, Learman & McCulloch, P.C.

(57) **ABSTRACT**

A fuel pump assembly for drawing fuel from a reservoir and supplying that fuel to an engine and including a fuel pumping module and an electric motor supported in a pump housing. The pumping module includes a module housing and an impeller that the motor rotates in an impeller cavity of the module housing. The impeller includes upper and lower vanes that move fluid through upper and lower portions of a semi-circular pumping channel, respectively. An exhaust port extends through the module housing and communicates with an exit passage of the pumping channel. An arcuate trench is disposed in the upper wall of the module housing and communicates with the outlet end of the pumping channel to redirect exiting fuel upward from the pumping module to a fuel pump housing outlet. The exit passage of the pumping channel extends tangentially outward into the trench. so that fuel exiting the pumping channel is relatively unimpeded.

13 Claims, 6 Drawing Sheets



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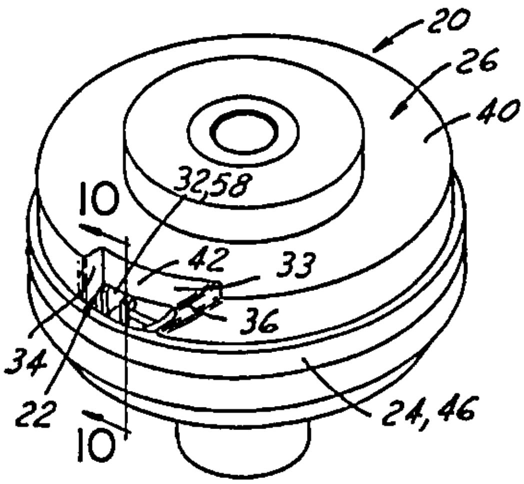
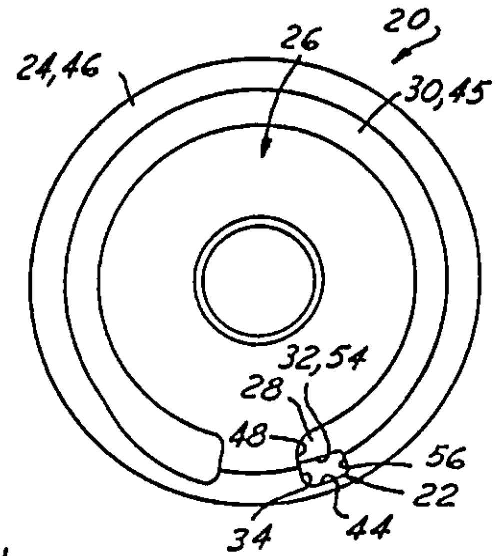


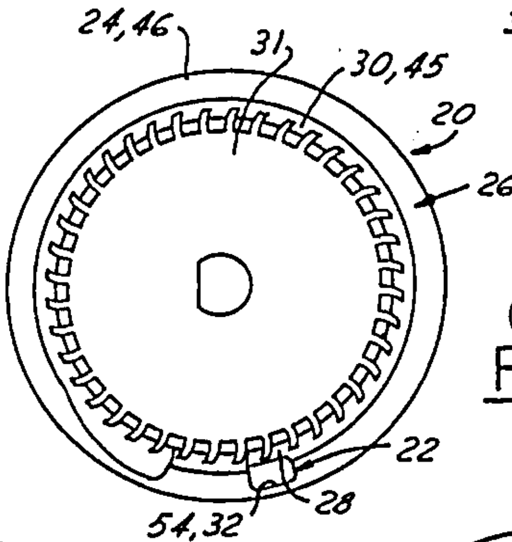
(Prior Art)

FIG. 1



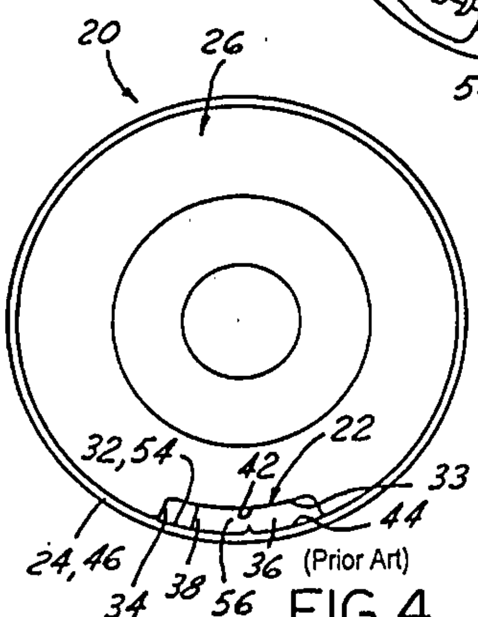
(Prior Art)

FIG. 2



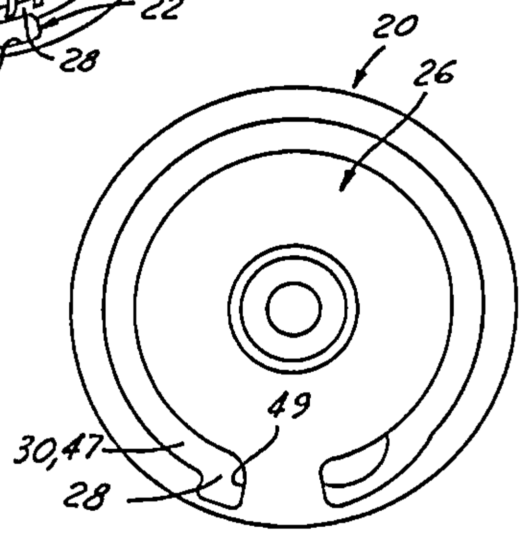
(Prior Art)

FIG. 3



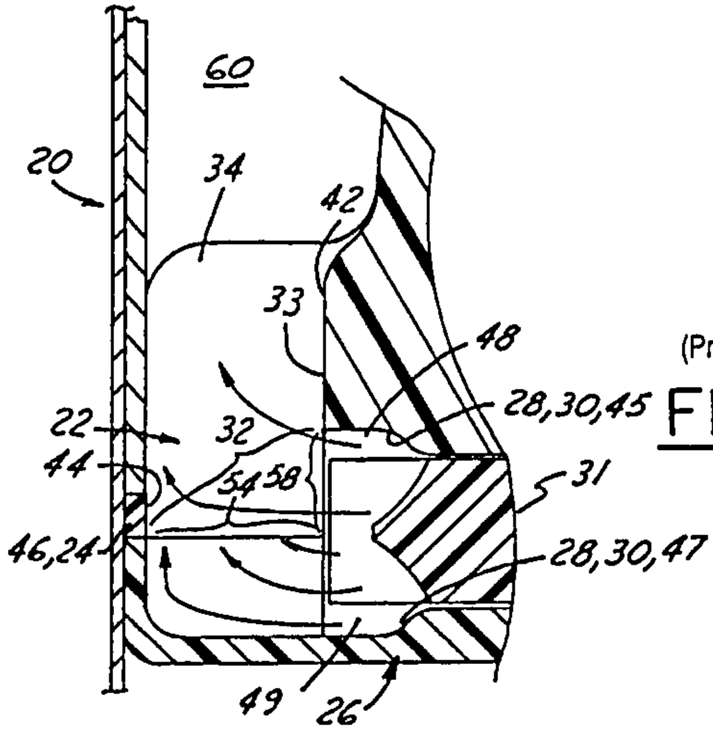
(Prior Art)

FIG. 4



(Prior Art)

FIG. 5



(Prior Art)

FIG.6

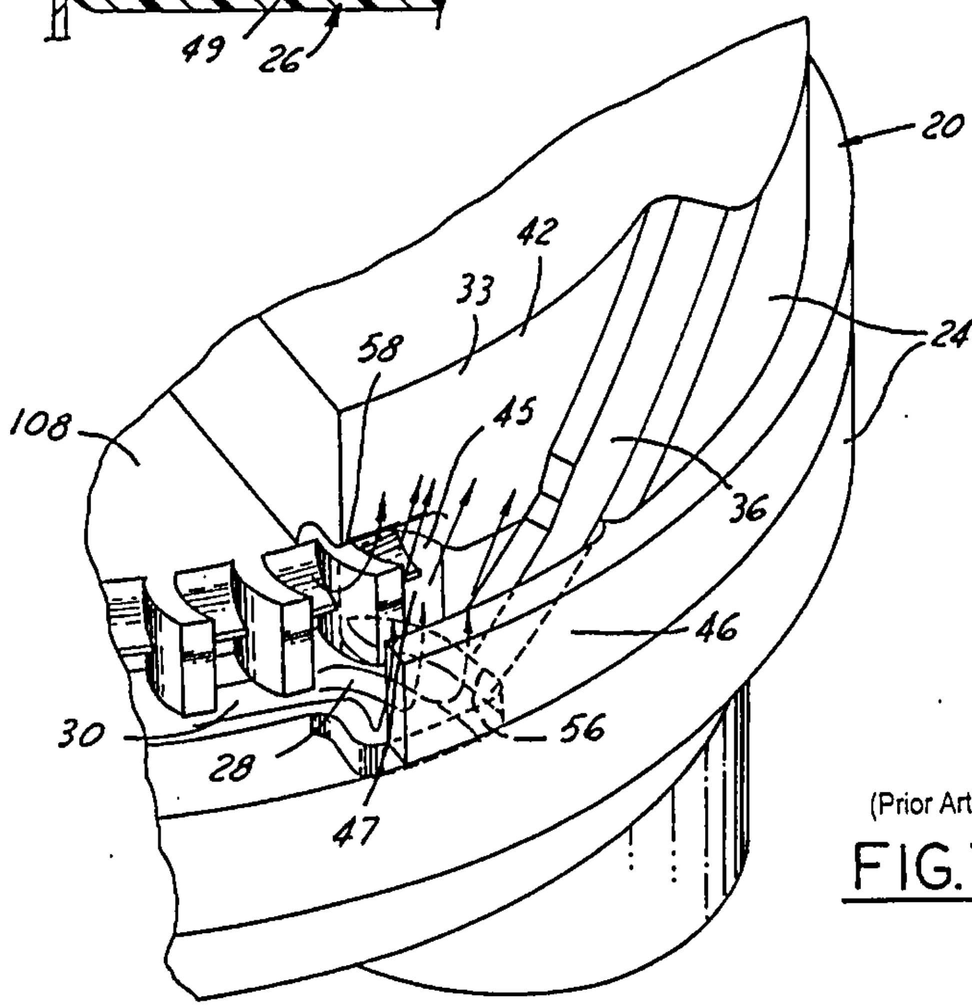


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FIG.7

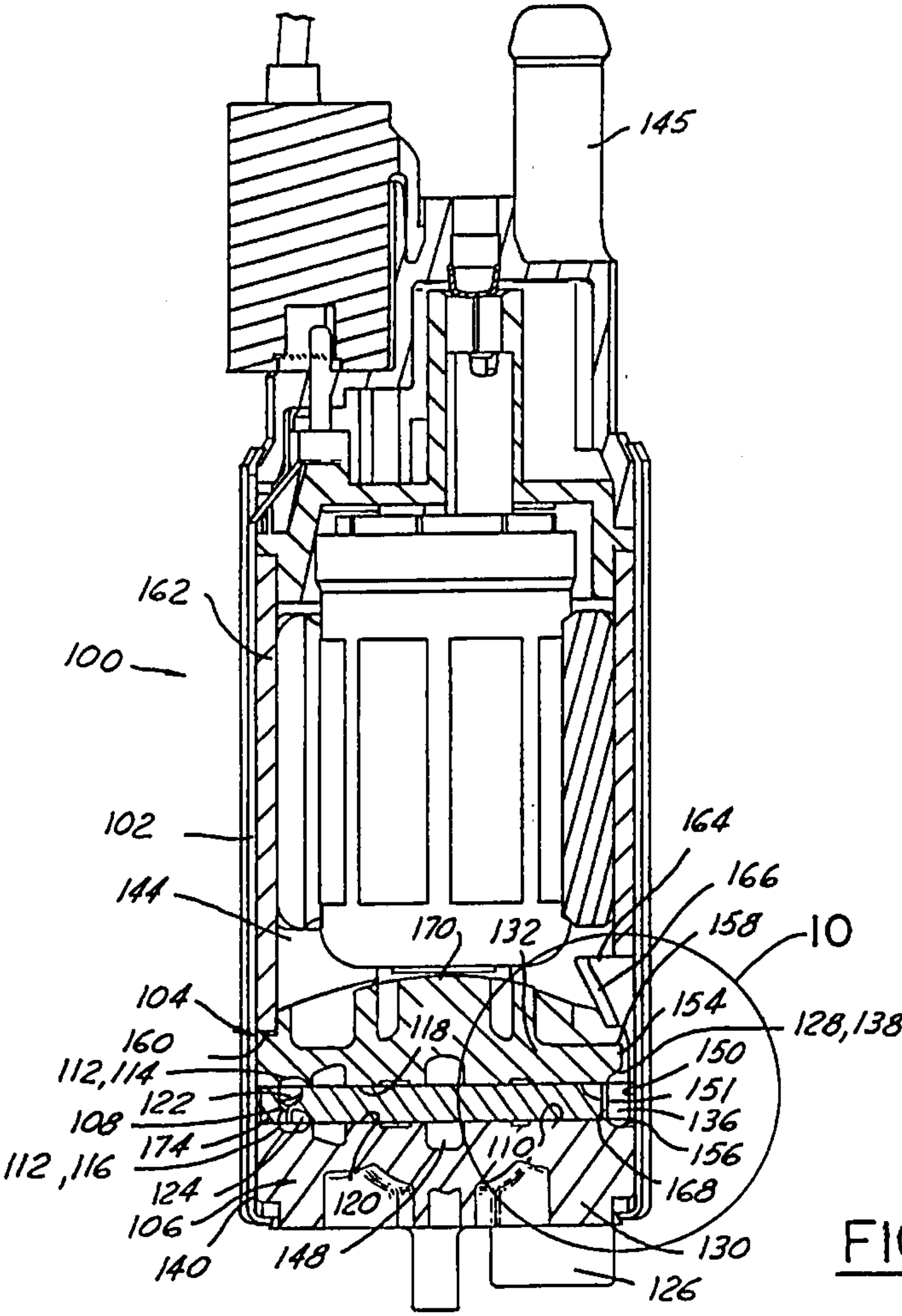
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FIG.8

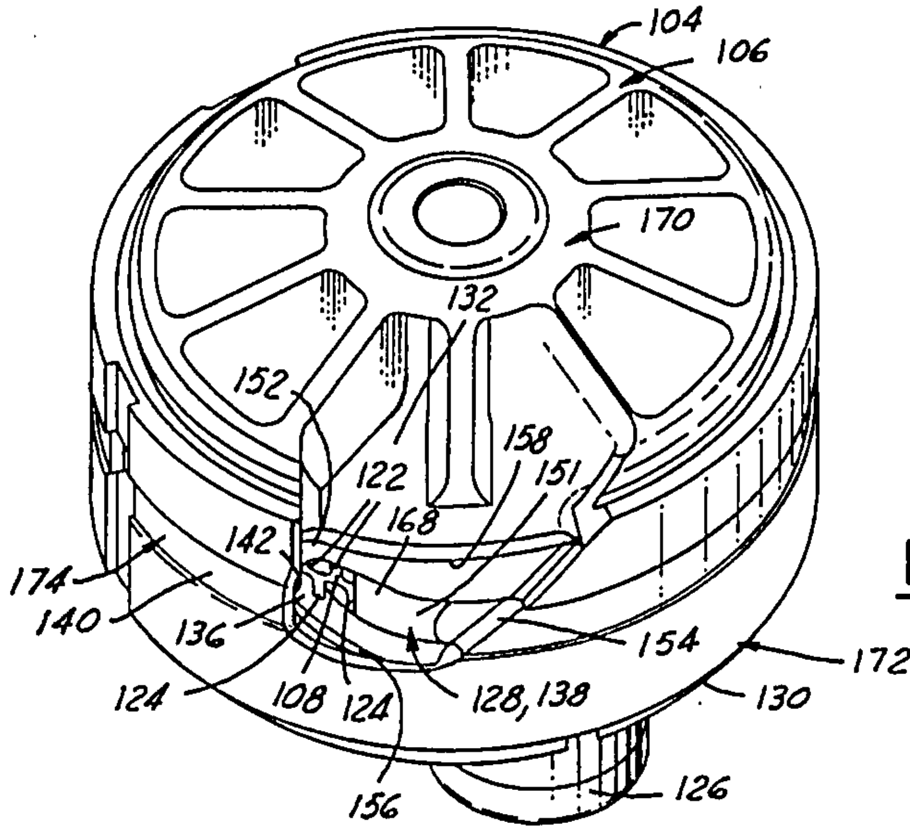
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FIG.9

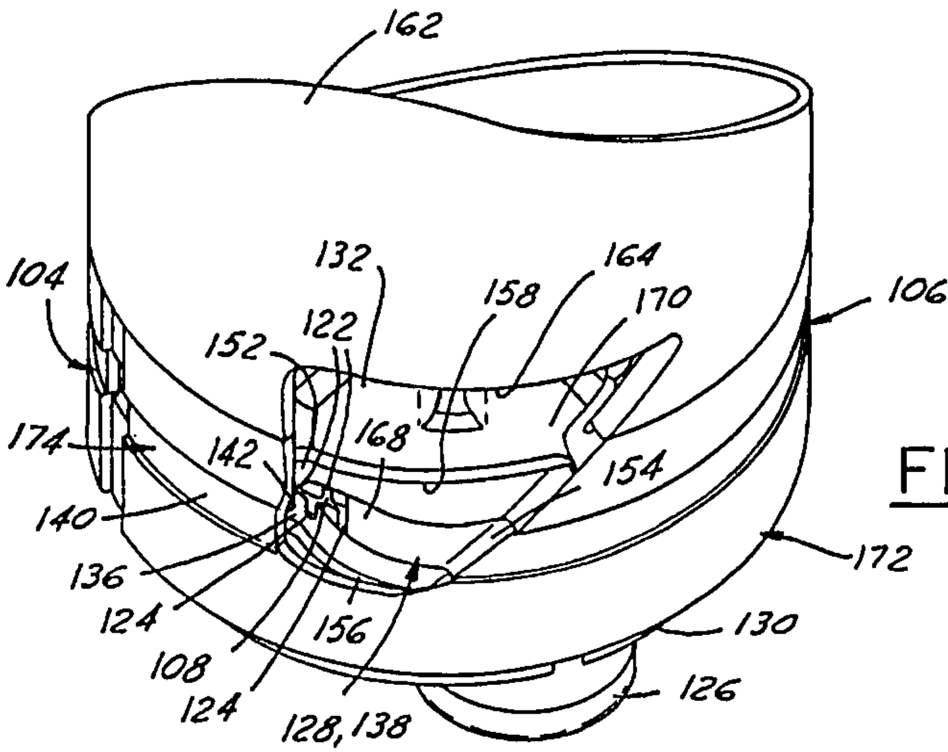
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FIG.10

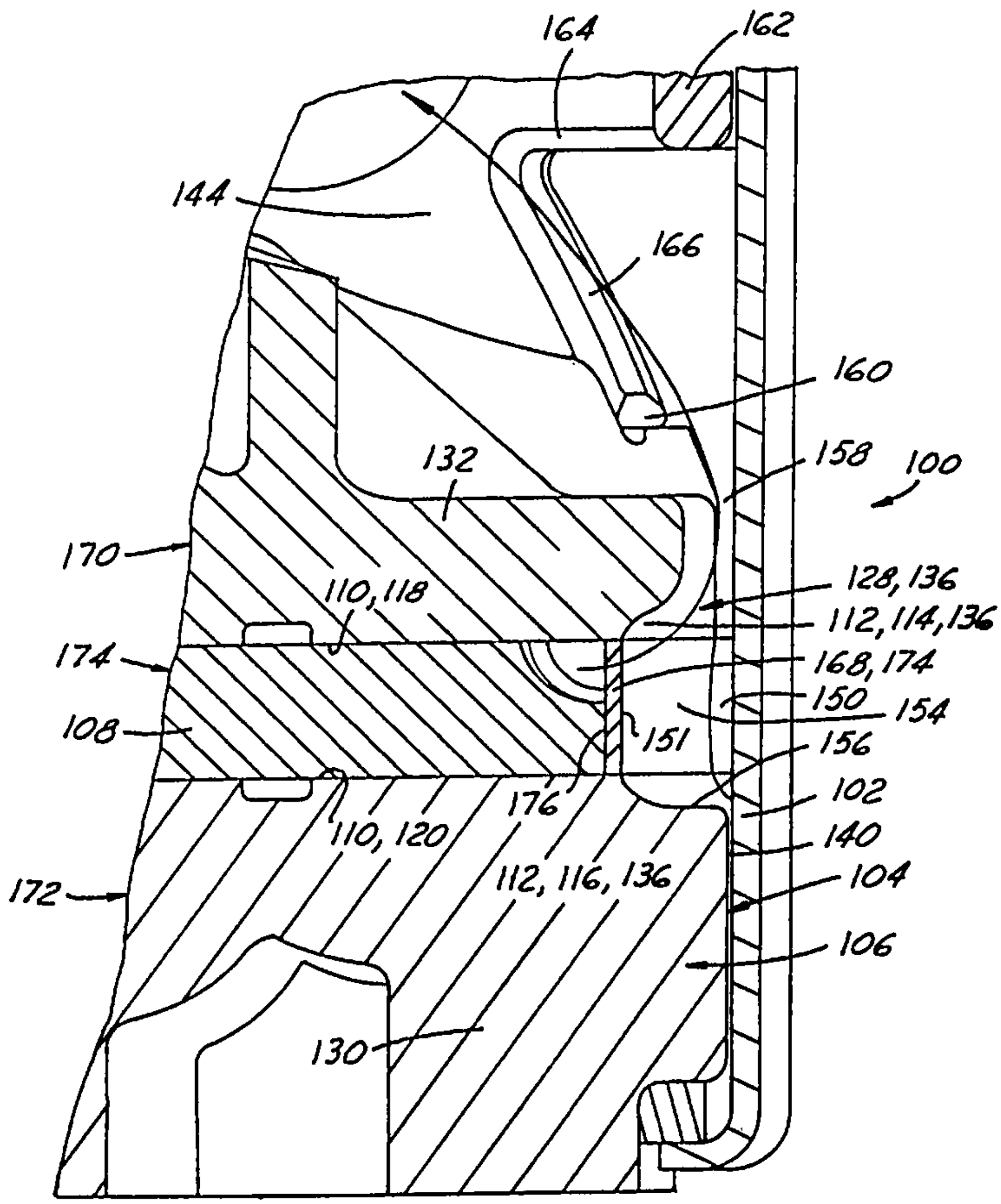
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FIG. 11

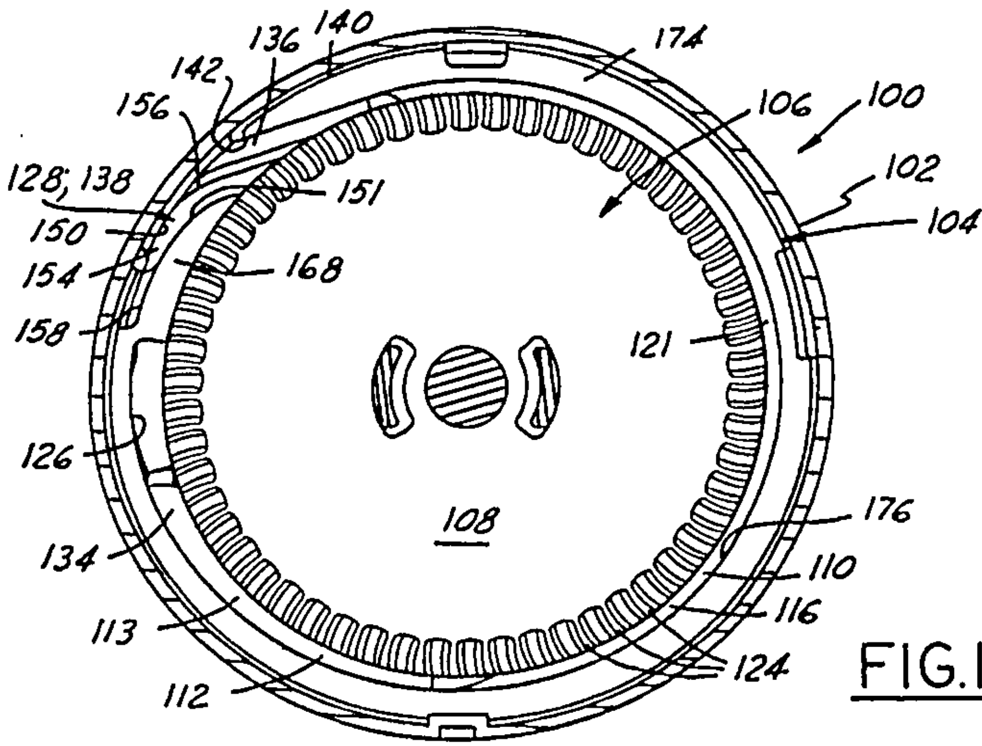

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FIG. 12

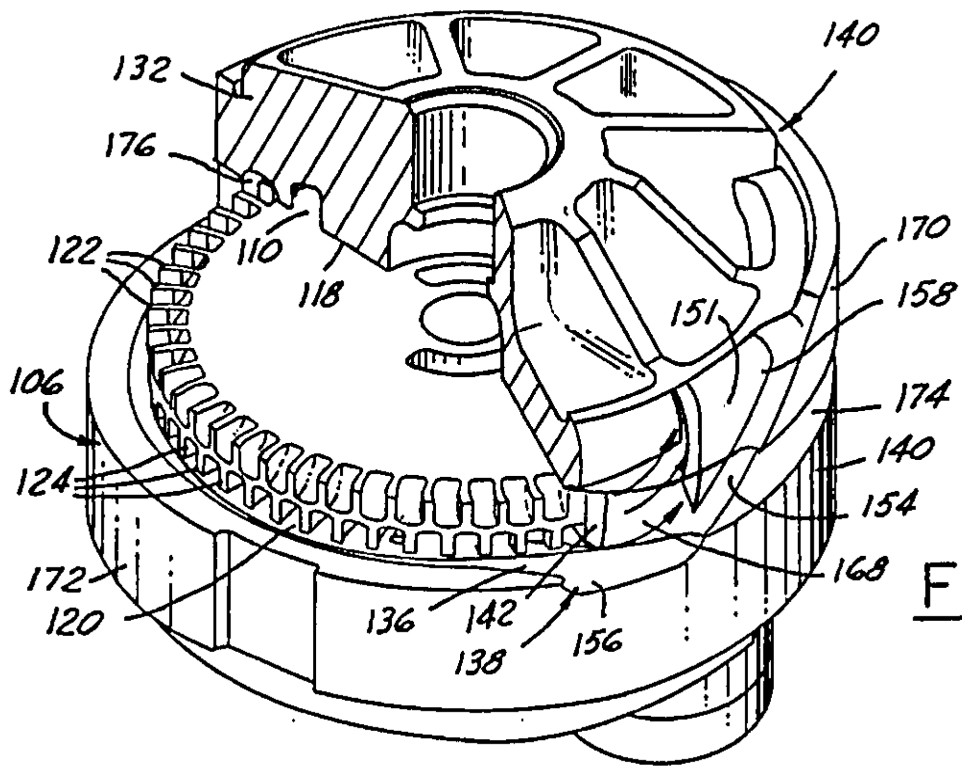

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FIG. 13

FUEL PUMPING ASSEMBLY

REFERENCE TO COPENDING APPLICATION

This application is a continuation-in-part of copending application, Ser. No. 09/527,722, filed Mar. 17, 2000, entitled "In-Tank Fuel Pump Reservoir" which in turn is a continuation-in-part of copending application, Ser. No. 09/282,053, filed Mar. 29, 1999, entitled "Fuel Pump With Low Pressure Motor Chamber".

TECHNICAL FIELD

This invention relates generally to a fuel pumping assembly for drawing fuel from a reservoir and supplying that fuel to an engine.

BACKGROUND OF THE INVENTION

It is known for a fuel pumping assembly to include an electric motor and a fuel pump module supported together in a housing. The fuel pump module in such an assembly will generally include a module housing, an impeller that is driven by the electric motor and rotates within an impeller cavity formed in the module housing, and a semi-circular pumping channel including upper and lower pumping channel portions formed around a circular periphery of the impeller cavity. The impeller may include axially upper and lower impeller vanes spaced around an outer circumferential periphery of the impeller that move fluid through the upper and lower portions of the pumping channel, respectively, as the impeller rotates within the impeller cavity. The module housing will also include an inlet port and an exhaust port that may extend axially through respective lower and upper walls of the module housing and connect with respective inlet and outlet ends of the pumping channel. To improve pump efficiency and reduce power requirements, it is desirable to shape the pumping channel and the exhaust port to minimize fluid losses.

For example, European Patent Application EPO 784 158 AZ discloses an electric motor regenerative turbine fuel pump assembly that improves efficiency by shaping the exhaust port of its pump module to include an arcuate trench in an upper wall of its module housing. As shown in FIGS. 1–7, the pump module 20 has an exhaust port 22 located along a portion of a circumferential sidewall 24 of a module housing 26 of the module 20 adjacent an exit end 28 of its pumping channel 30 in which an impeller 31 is received. The exhaust port 22 also includes an opening 32 that leads from the outlet end 28 of the pumping channel 30 into the trench 33. The trench 33 is defined by a generally vertical trench end wall 34 disposed upstream from a ramp 36 that inclines from a floor 38 of the trench 33, in a downstream direction, i.e., the direction of impeller rotation, to an upper surface 40 of the module housing 26. The trench 33 is further defined by an arcuate radially inner wall 42 that stands opposite and parallel to an arcuate radially outer wall 44. A thin circumferential band of material 46 surrounds the module housing 26 and defines the outer wall 44 of the trench 33. However, the exhaust port opening 32 is disposed radially outward from the impeller 31 and the exit end 28 of the pumping channel 30. As best shown in FIGS. 6 and 7, this requires fuel exiting upper and lower portions 45, 47 of the pumping channel 30 to impact respective upper and lower channel exit end walls 48, 49 of the upper and lower portions 45, 47 of the pumping channel 30 before turning radially outward to exit through the exhaust port opening 32 resulting in fluid losses. In other words, the exit end 28 of the pumping channel 30 forms an elbow redirecting fluid flow radially outward from the channel 30 and through the exhaust port opening 32.

The exhaust port opening 32 includes a generally rectangular horizontal portion 54 defined on three sides by the trench end wall 34, the outer wall 44 and a leading or upstream edge 56 of the ramp 36. A fourth side of the horizontal portion 54 of the exhaust port opening 32 is defined by an imaginary line extending through space between respective radially inner ends of the sides defined by the trench end wall 34 and the upstream edge 56 of the ramp 36. The exhaust port opening 32 also includes a generally rectangular vertical portion 58 formed into the inner wall 42. The vertical portion 58 of the exhaust port opening 32 is positioned to allow fuel to exit directly from the upper portion 45 of the pumping channel 30 into the exhaust port trench 33. The horizontal portion 54 of the exhaust port opening 32 is formed in the floor 38 of the trench 33 to allow fuel to exit vertically upward from the lower portion 47 of the exit end 28 of the pumping channel 30 and into the trench 33. However, fuel exiting vertically through the horizontal portion 54 of the exhaust port opening 32 necessarily impinges on fuel exiting laterally from the vertical portion 58 of the exhaust port opening 32 resulting in impingement mixing at the opening and associated turbulence and fluid losses.

As best shown in FIG. 6, the exhaust port trench 33 is shaped to discharge the mixed upper and lower fuel flows up the ramp 36 and generally vertically away from the pumping module 20 into a chamber 60 of the fuel pump housing 62 that contains the electric motor. The fuel continues past the motor and out an outlet of the pump housing to supply fuel under pressure to an operating engine. The fuel pumping assembly of the Denso pump includes an electric motor (not shown) connected to and constructed to rotate the impeller.

SUMMARY OF THE INVENTION

The invention is a fuel pumping assembly that includes a fuel pump module supported in a fuel pump housing. The fuel pump module includes an impeller rotatably supported within an impeller cavity formed in a pump module housing, and a generally semi-circular pumping channel formed in the housing around a generally circular periphery of the impeller cavity. The impeller includes axially upper and lower impeller vanes spaced around an outer circumferential periphery of the impeller that are configured and positioned to move fluid through the pumping channel as the impeller rotates within the impeller cavity. The module housing includes inlet and exhaust ports communicating with respective inlet and exit passages of the pumping channel.

The exit passage of the pumping channel extends generally tangentially outward through the sidewall of the module housing. This aligns the exhaust port with the tangential flow of fuel from the exit passage of the pumping channel such that fuel exits the pumping channel relatively unimpeded and flows smoothly into the trench. Therefore, a fuel pumping assembly constructed according to the invention is able to pump fuel more efficiently.

Preferably, the cross-sectional area of the exit passage of the pumping channel gradually increases toward the exhaust port which further reduces back pressure on the impeller and increases efficiency. The exit passage of the pumping channel and the exhaust port opening are constructed to allow a lower fuel stream exiting the lower portion of the pumping channel to remain parallel to and below an upper fuel stream exiting the upper portion of the pumping channel while flowing into the exhaust port trench which reduces fluid losses by avoiding impingement mixing. The exhaust port opening and trench are constructed to allow lower and upper

fuel streams from the lower and upper portions of the pumping channel, respectively, to both exit laterally into the exhaust port trench which prevents uneven back pressure on the impeller upper and lower vanes and unbalanced impeller loads that would otherwise result in reduced efficiency or even spin welding of the impeller to the impeller chamber. Preferably, the pump housing surrounding the fuel pump module defines a radially outer wall of the exhaust port trench precluding the need to form such a wall while molding the module housing. The trench may include a ramp that smoothly redirects exiting fuel axially upward from the pumping module, again improving efficiency and reducing power requirements.

Objects, features and advantages of this invention include a turbine pump that has significantly improved efficiency, may be readily incorporated into existing fuel pump designs, has significantly improved balancing and decreases axial loads on the impeller particularly during high flow rate operating conditions, and is of relatively simple design and economical manufacture and assembly and in service has a significantly increased useful life.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, features and advantages of this invention will be apparent from the following detailed description of the preferred embodiment(s) and best mode, appended claims, and accompanying drawings in which:

FIG. 1 is a perspective view of a fuel pump module from a prior art electric motor regenerative turbine fuel pump;

FIG. 2 is a bottom view of an upper cap portion of the prior art fuel pump module of FIG. 1;

FIG. 3 is a bottom view of the upper cap and impeller of the prior art fuel pump module of FIG. 1;

FIG. 4 is a top view of the upper cap of FIG. 2;

FIG. 5 is a top view of a base portion of the prior art fuel pump module of FIG.1;

FIG. 6 is an enlarged cross-sectional view of a peripheral region of the prior art fuel pump module of FIG. 1 taken along line 6—6 of FIG. 1 and with arrowed lines indicating fuel flow paths;

FIG. 7 is a perspective view of the prior art fuel pump module of FIG. 1 with arrowed lines indicating fluid flow paths;

FIG. 8 is a cross-sectional front view of a fuel pump assembly embodying the invention;

FIG. 9 is a perspective view of a fuel pump module of the fuel pump assembly of FIG. 8;

FIG. 10 is a perspective view of a flux tube of the fuel pump assembly of FIG. 8 supported on the fuel pump module of FIG. 9.;

FIG. 11 is an enlarged fragmentary cross-sectional view of a peripheral region of the fuel pump module of FIG. 8 taken from within circle 10 of FIG. 8;

FIG. 12 is a bottom view of a top cover, impeller and guide ring of the fuel pump module of FIG. 8; and

FIG. 13 is a partially broken-away front perspective view of the inventive fuel pump module of FIG. 8 with arrowed lines indicating fluid flow paths.

DETAILED DESCRIPTION

A fuel pumping assembly for drawing fuel from a reservoir and supplying that fuel at increased pressure to a desired location such as an engine is shown at 100 in FIGS. 8–13. The assembly 100 includes a fuel pump housing 102 and a

fuel pump module 104 supported in the pump housing 102. The fuel pump module 104 includes a module housing 106 and an impeller 108 that is rotatably supported within an impeller cavity 110 formed in the module housing 106. The module housing 106 also includes a generally semi-circular pumping channel 112 hving upper and lower channel portions 114, 116 formed into a roof 118 and a floor 120 of the impeller cavity 110, respectively, around a generally circular periphery of the impeller cavity 110.

The upper and lower channel portions 114, 116 are separated along an approximate 120° high pressure portion of their lengths by a rib 121 that extends radially inward toward the impeller from an outer circumferential wall of the pumping channel 112.

The impeller 108 has axially upper and lower impeller vanes 122, 124 spaced around an outer circumferential periphery of the impeller 108 that are configured and positioned to move fluid through the upper and lower pumping channel portions 114, 116 respectively, as the impeller 108 rotates within the impeller cavity 110. The module housing 106 includes inlet and exhaust ports 126, 128 that extend generally axially through respective lower and upper walls 130, 132 of the module housing 106 and communicate with respective inlet and exit passages 134, 136 of the pumping channel 112.

The exhaust port 128 includes an arcuate trench 138 formed in the upper wall 132 of the module housing 106 along a portion of a circumferential side wall 140 of the module housing 106 adjacent the exit passage 136 of the pumping channel 112. The exhaust port 128 also includes an opening 142 from the exit end 136 of the pumping channel 112 into the trench 138. As is best shown in FIG. 8, the exhaust port trench 138 is configured or shaped and positioned to redirect exiting fuel upward from the pumping module 104 into a chamber 144 of the fuel pump housing 102 that contains the electric motor and that leads to a fuel pump assembly outlet 145. As is also shown in FIG. 8, the assembly 100 also includes an electric motor 146 that is supported in the pump housing 102 and is drivingly connected to the impeller 108 by a drive shaft 148. When energized, the electric motor causes the impeller 108 to rotate within the impeller cavity 110.

As is best shown in FIG. 12, the exit passage 136 of the pumping channel 112 extends tangentially outward through the side wall 140 of the module housing 106 and into an upstream end of the trench 138. The exhaust port opening 142 is aligned with the tangential flow of fuel from the exit passage 136 of the pumping channel 112 such that fuel exiting the pumping channel 112 is relatively unimpeded and flows smoothly into the trench 138. To reduce back pressure on the impeller vanes 122, 124, the cross-sectional area of the exit passage 136 of the pumping channel 112, measured normal to the flow direction, increases gradually where the exit passage 136 of the channel opens out into the trench 138.

As shown in FIGS. 8–13, the exit passage 136 of the pumping channel 112 has a generally rectangular cross-section, as viewed in the direction of fluid flow, with rounded corners. The exhaust port opening 142, being defined by the exit end 136 of the pumping channel 112 where it merges into the trench 138, is also roughly rectangular and is disposed generally normal to the flow direction of fuel exiting the pumping channel 112 as best shown in FIG. 12. As is best shown in FIGS. 9, 10, 11 and 13, the exit passage 136 of the pumping channel 112 and the exhaust port 128 are configured, i.e., shaped and positioned, to allow

a lower fuel stream exiting the lower portion of the pumping channel **112** to remain parallel to and below an upper fuel stream exiting the upper portion of the pumping channel **112** while flowing into the exhaust port trench **138**. More specifically, the exit passage **136** of the pumping channel **112** and the exhaust port opening **142** have vertical (axial) dimensions that exceed the axially-measured thickness of the impeller **108** at the impeller vanes **122, 124**. The exit passage **136** of the pumping channel **112** and the exhaust port **128** are also aligned axially with the impeller **108** so as to expose both the upper and lower impeller vanes **122, 124** and to allow the upper and lower fuel streams to exit laterally (along a path in a plane perpendicular to the axis of the impeller) into the exhaust port trench **138** from the upper and lower impeller vanes **122, 124**. The exit passage **136** of the pumping channel **112** and the exhaust port **128** are not shaped or positioned to physically separate the upper and lower fuel streams from one another. Instead, the exit end **136** of the pumping channel **112** includes smooth continuous, generally horizontal contours. These contours allow the upper and lower fuel streams to continue moving in a generally parallel manner through the exhaust port **128** rather than forcing their flow paths to cross as they enter the exhaust port trench **138**. In other words, contours defining the exit passage **136** of the pumping channel **112** smoothly flow out into contours defining the exhaust port trench **138** at the exhaust port opening **142**. This prevents forced mixing of upper and lower streams and further reduces fluid losses that might otherwise be experienced at the exhaust port **128**.

The pump housing **102** surrounds the fuel pump module **104** and defines an arcuate, radially outer wall **150** of the exhaust port trench **138** disposed opposite an arcuate, radially inner wall **151** of the trench **138** as shown in FIGS. **8, 11** and **12**. The trench **138** is further defined by a generally vertical end wall **152** (FIGS. **10** and **11**) disposed upstream from a ramp **154** that inclines upwardly from a floor **156** of the trench **138**, in a downstream direction, i.e., the direction of impeller **108** rotation, to a top surface of the module housing **106**.

The exit passage **136** of the pumping channel **112** and the exhaust port opening **142** are configured to align the upper and lower fuel streams with the exhaust port trench **138**. The contours of the exhaust port trench **138** smoothly divert the upper and lower fuel streams from their tangential path from the pumping channel **112** to a generally circumferential flow path. The trench **138** contours then smoothly guide this generally circumferential flow of the upper and lower fuel streams up the ramp **154** and out a narrow arcuate upper discharge aperture **158** of the exhaust port trench **138**.

As shown in FIGS. **8, 10** and **11**, a lower edge **160** of a flux tube **162** of the electric motor **146** is disposed concentrically within the pump housing **102** and abuts an outer circumferential marginal portion of the upper wall **132** of the housing covering the trench **138**. The lower edge **160** of the flux tube **162** therefore includes a relieved portion **164** disposed axially over the trench **138** so as not to impede fuel exiting the trench **138**. As best shown in FIG. **10**, the shape of the relieved portion **164** of the flux tube **162** is generally trapezoidal with one wall **166** of the relieved portion **164** angled to align with and continue the ramp **154** of the exhaust port trench **138**.

As is best shown in FIG. **12**, the inner wall **151** of the trench **138** is disposed on an arcuately wedge-shaped stripper zone partition **168** configured to block flow from the upper and lower high pressure pumping channel portions **114, 116** immediately downstream from the exit passage **136** of the pumping channel **112** into the low pressure inlet area **126** of the pumping channel **112**. The stripper zone partition **168** improves pump efficiency by preventing a significant amount of high-pressure fuel at the exit passage **136** of the pumping channel **112** from escaping past the impeller **108** to the low-pressure intake end of the pumping channel **112**.

The pumping module housing **106** includes a top cover **170** defining the upper wall **132** of the module housing **106**, a base **172** defining the lower wall **130** of the module housing **106**, and a guide ring **174** disposed between the top cover **170** and the base **172**. The top cover **170** defines the roof **118** of the impeller cavity **110**, the base **172** defines the floor **120** of the impeller cavity **110** and the guide ring **174** defines a circumferential outer wall **176** of the impeller cavity **110**.

The exit passage **136** of the pumping channel **112** extends tangentially outward through and is partially defined by the guide ring **174**. The exit passage **136** of the pumping channel **112** is also formed into the top cover **170**, the base **172** and the guide ring **174**. The exhaust port **128** is also formed into the top cover **170**, the base **172** and the guide ring **174**. A portion of the exhaust port trench **138** and a portion of the exhaust port opening **142** are similarly formed into the guide ring **174**.

In operation, the electric motor is energized to rotate the impeller within the module housing which draws fluid axially upward through the inlet port **126** and into a low-pressure region **113** of the pumping channel **112**. After traveling approximately 90° along the pumping channel **112**, fluid in the upper channel portion **114** is separated from fluid in the lower channel portion **116** by the rib **121**. Fluid pressure increases significantly for the next approximately 120° of travel through the pumping channel and along the entire length of the rib **121** separating the fluid being propelled by the upper and lower impeller vanes **122, 124**, respectively. From this high-pressure region along the rib **121**, the fluid passes into the exit passage **136** of the pumping channel **112**. The rib **121** terminates at this point and the fluid flowing out from the upper and lower channel portions **114, 116**; rather than being forced to mix at this point, continues in a parallel flow pattern along the exit passage **136** and into the trench **138**. As the fluid passes from the exit passage **136** into the trench **138**, the outer wall **150** of the trench **138** smoothly redirects the fluid from a tangential flow to a circumferential flow. The fluid is then directed smoothly upward along the ramp **154** and past the top surface of the module housing **106** through the narrow arcuate upper discharge aperture **158** of the exhaust port trench **138**. As the fuel exits the trench **138**, it continues in a generally circumferential upwardly spiraling motion through the relieved portion **164** of the flux tube **162** and along the ramped wall **166** of the relieved portion **164**. The flow continues out of the relieved portion **164** through the chamber **144** of the fuel pump housing **102** that contains the electric motor **146**, then flows past the electric motor between the flux tube **162** and the rotor and exits the fuel pump assembly through a fuel pump assembly outlet **145**.

This description is intended to illustrate certain embodiments of the invention rather than to limit the invention. Therefore, it uses descriptive rather than limiting words.

Obviously, it's possible to modify this invention from what the description teaches. Within the scope of the claims, one may practice the invention other than as described.

What is claimed is:

1. A fuel pump assembly comprising:

a fuel pump housing;

a fuel pump module supported in the pump housing and including:

a module housing including inlet and exhaust ports;

an impeller that is rotatably supported within an impeller cavity formed in the module housing and rotatably driven by an electric motor, the impeller including axially upper and lower impeller vanes spaced around an outer circumferential periphery of the impeller;

a generally semi-circular pumping channel formed in the housing around a circular periphery of the impeller cavity, the impeller vanes being configured and positioned to move fluid through the pumping channel as the impeller rotates within the impeller cavity, the inlet and exhaust ports communicating with respective inlet and exit passages of the pumping channel;

the exit passage of the pumping channel extending generally tangentially outward through the side wall of the module housing, the exhaust port being aligned with the tangential flow of fuel from the exit passage of the pumping channel such that fuel exits the pumping channel relatively unimpeded.

2. A fuel pumping assembly as defined in claim 1 in which the cross-sectional area of the exit passage of the pumping channel increases gradually toward the exhaust port.

3. A fuel pump assembly comprising:

a fuel pump housing;

a fuel pump module supported in the pump housing and including:

a module housing including inlet and exhaust ports, the exhaust port extending generally axially through a lower wall of the module housing;

an impeller rotatably supported within an impeller cavity formed in the module housing and rotatably driven by an electric motor, the impeller including axially upper and lower impeller vanes spaced around an outer circumferential periphery of the impeller;

a generally semi-circular pumping channel including upper and lower pumping channel portions formed into the housing around a circular periphery of the impeller cavity, the impeller vanes being configured and positioned to move fluid through the upper and lower portions of the pumping channel, respectively, as the impeller rotates within the impeller cavity, the inlet and exhaust ports intersecting respective inlet and exit passages of the pumping channel;

the exhaust port including:

a trench formed in the module housing along a portion of a circumferential side wall of the module housing adjacent the outlet end of the pumping channel and opening axially upward;

an opening from the exit passage of the pumping channel into the trench; and

the exit passage of the pumping channel and the exhaust port opening being configured to allow a lower fuel stream propelled from a lower portion of the exit passage by the lower impeller vanes to remain parallel to and below an upper fuel stream propelled from an upper portion of the exit passage by the upper impeller vanes while flowing into the exhaust port trench.

4. A fuel pump assembly comprising:

a fuel pump housing;

a fuel pump module supported in the pump housing and including:

a module housing including inlet and exhaust ports, the exhaust port extending generally axially through a lower wall of the module housing;

an impeller rotatably supported within an impeller cavity formed in the module housing and rotatably driven by an electric motor, the impeller including axially upper and lower impeller vanes spaced around an outer circumferential periphery of the impeller;

a generally semi-circular pumping channel including upper and lower pumping channel portions formed into the housing around a circular periphery of the impeller cavity, the impeller vanes being configured and positioned to move fluid through the upper and lower portions of the pumping channel, respectively, as the impeller rotates within the impeller cavity, the inlet and exhaust ports intersecting respective inlet and exit passages of the pumping channel;

the exhaust port including:

a trench formed in the module housing along a portion of a circumferential side wall of the module housing adjacent the outlet end of the pumping channel and opening axially upward;

an opening from the exit passage of the pumping channel into the trench; and

the exhaust port opening and trench being configured to allow lower and upper fuel streams from lower and upper portions of the exit passage, respectively, to both exit directly into the exhaust port trench.

5. A fuel pump assembly comprising:

a fuel pump housing;

a fuel pumping module supported in the pump housing and including:

a module housing including inlet and exhaust ports, the exhaust port extending generally axially through a lower wall of the module housing;

an impeller rotatably supported within an impeller cavity formed in the module housing and rotatably driven by an electric motor, the impeller including axially upper and lower impeller vanes spaced around an outer circumferential periphery of the impeller;

a generally semi-circular pumping channel including upper and lower pumping channel portions formed into the housing around a circular periphery of the impeller cavity, the impeller vanes being configured and positioned to move fluid through the upper and lower portions of the pumping channel, respectively, as the impeller rotates within the impeller cavity, the inlet and exhaust ports communicating with respective inlet and exit passages of the pumping channel;

the exhaust port including:

a trench formed in the module housing along a portion of a circumferential side wall of the module housing adjacent the outlet end of the pumping channel and opening axially upward; and

an opening from the exit passage of the pumping channel into the trench;

the pump housing surrounding the fuel pumping module and defining a radially outer wall of the exhaust port trench disposed opposite a radially inner wall of the trench.

6. A fuel pumping assembly as defined in claim 1 in which the trench is defined by an end wall disposed upstream from a ramp that inclines from a floor of the trench, in a downstream direction to a top surface of the module housing.

7. A fuel pumping assembly as defined in claim 6 in which the exit end of the pumping channel and the exhaust port opening are configured to align the upper and lower fuel

streams with the exhaust port trench and the exhaust port trench is configured to smoothly guide the upper and lower fuel streams up the ramp.

8. A fuel pumping assembly as defined in claim 1 in which the pumping module housing includes a top cover defining the upper wall of the housing, a base defining the lower wall of the housing, and a guide ring disposed between the top cover and the base; the top cover defines the roof of the impeller cavity, the base defines the floor of the impeller cavity and the guide ring defines a circumferential outer wall of the impeller cavity.

9. A fuel pumping assembly as defined in claim 8 in which the exhaust end of the pumping channel extends tangentially outward through and is at least partially defined by the guide ring.

10. A fuel pumping assembly as defined in claim 8 in which at least a portion of the exhaust port trench is formed into the guide ring.

11. A fuel pumping assembly as defined in claim 8 in which at least a portion of the exhaust port opening is formed into the guide ring.

12. A fuel pumping assembly as defined in claim 8 in which the exit end of the pumping channel is formed into the top cover, the base and the guide ring.

13. A fuel pumping assembly as defined in claim 8 in which the exhaust port is formed into the top cover, the base and the guide ring.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,227,819 B1
DATED : May 8, 2001
INVENTOR(S) : Bryan J. Gettel et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,
The name of the inventors should read as follows:
Item [75] Bryan J. Gettel, Pigeon;
Glenn A. Moss, Cass City;
Joseph M. Ross, Millington,
Bradley L. Uffelman, Caro, all of MI (US)

Signed and Sealed this

Twenty-fifth Day of December, 2001

Attest:

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

Attesting Officer

05-74325.

CIVIL COVER SHEET

COUNTY IN WHICH THIS ACTION AROSE: Macomb

...-44 civil cover sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required ...law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for use of the Clerk of Court for the purpose of initiating the civil docket sheet.

I. (a) PLAINTIFFS
TI GROUP AUTOMOTIVE SYSTEMS, LLC, a Delaware Limited Liability Company

(b) County of Residence of First Listed: Macomb

(C) Attorney's (Firm Name, Address, and Telephone Number)
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DEFENDANTS
PERFORMANCE AFTERMARKET PARTS GROUP, LTD., a Texas Limited Partnership

County of Residence of First Listed: foreign

NOTE: IN LAND CONDEMNATION CASES, USE THE LOCATION OF THE LAND INVOLVED.

Attorneys (If Known)

Nancy G. Edmunds.
Mag. Pepe.

II. BASIS OF JURISDICTION (Place an "X" in One Box Only)

- ☐ 1 U.S. Government Plaintiff
- ☒ 3 Federal Question (U.S. Government Not a Party)
- ☐ 2 U.S. Government Defendant
- ☐ 4 Diversity (Indicate Citizenship of Parties in Item 111)

III. CITIZENSHIP OF PRINCIPAL PARTIES (Place an "X" in One Box for Plaintiff and One Box for Defendant)
(For Diversity Cases Only)

	PLA	DEF		PLA	DEF
Citizen of This State	☐ 1	☐ 1	Incorporated or Principal Place of Business In This State	☐ 4	☐ 4
Citizen of Another	☐ 2	☐ 2	Incorporated and Principal of Business In Another State	☐ 5	☐ 5
Citizen or Subject of a Foreign Country	☐ 3	☐ 3	Foreign Nation	☐ 6	☐ 6

IV. NATURE OF SUIT (Place an "X" in One Box Only)

CONTRACT
- ☐ 110 Insurance
- ☐ 120 Marine
- ☐ 130 Miller Act
- ☐ 140 Negotiable Instrument
- ☐ 150 Recovery of Overpayment and Enforcement of Judgment
- ☐ 151 Medicare Act
- ☐ 152 Recovery of Defaulted Student Loans (Excl. Veterans)
- ☐ 153 Recovery of Overpayment of Veteran's Benefits
- ☐ 160 Stockholders' Suits
- ☐ 190 Other Contract
- ☐ 195 Contract Product Liability

REAL PROPERTY
- ☐ 210 Land Condemnation
- ☐ 220 Foreclosure
- ☐ 230 Rent Lease & Ejectment
- ☐ 240 Torts to Land
- ☐ 245 Tort Product Liability
- ☐ 290 All Other Real Property

TORTS

PERSONAL INJURY
- ☐ 310 Airplane
- ☐ 315 Airplane Product Liability
- ☐ 320 Assault Libel And Slander
- ☐ 330 Federal Employers' Liability
- ☐ 340 Marine
- ☐ 345 Marine Product Liability
- ☐ 350 Motor Vehicle
- ☐ 355 Motor Vehicle Product Liability
- ☐ 360 Other Personal Injury

PERSONAL INJURY
- ☐ 362 Personal Injury-Med. Malpractice
- ☐ 365 Personal Injury - Product Liability
- ☐ 368 Asbestos Personal Injury Product Liability

PERSONAL PROPERTY
- ☐ 370 Other Fraud
- ☐ 371 Truth in Lending
- ☐ 380 Other Personal Property Damage
- ☐ 385 Property Damage Product Liability

CIVIL RIGHTS
- ☐ 441 Voting
- ☐ 442 Employment
- ☐ 443 Housing/ Accommodations
- ☐ 444 Welfare
- ☐ 440 Other Civil Rights

PRISONER PETITIONS
- ☐ 510 Motions to Vacate Sentence Habeas Corpus:
- ☐ 530 General
- ☐ 535 Death Penalty
- ☐ 540 Mandamus & Other
- ☐ 550 Civil Rights
- ☐ 555 Prison Condition

FORFEITURE/PENALTY
- ☐ 610 Agriculture
- ☐ 620 Other Food & Drug
- ☐ 625 Drug Related Seizure of Property 21:881
- ☐ 630 Liquor Laws
- ☐ 640 R.R. & Truck
- ☐ 650 Airline Regs.
- ☐ 660 Occupational Safety/Health
- ☐ 690 Other

LABOR
- ☐ 710 Fair Labor Standards Act
- ☐ 720 Labor/Mgmt. Relations
- ☐ 730 Labor/Mgmt. Reporting & Disclosure Act
- ☐ 740 Railway Labor Act
- ☐ 790 Other Labor Litigation
- ☐ 791 Empl. Ret. Inc. Security Act

BANKRUPTCY
- ☐ 422 Appeal 28 USC 158
- ☐ 423 Withdrawal 28 USC 157

PROPERTY RIGHTS
- ☐ 820 Copyrights
- ☒ 830 Patent
- ☐ 840 Trademark

SOCIAL SECURITY
- ☐ 861 HIA (1395ff)
- ☐ 862 Black Lung (923)
- ☐ 863 DIWC/DIWW (405(g))
- ☐ 864 SSID Title XVI
- ☐ 865 RSI (405(g))

FEDERAL TAX SUITS
- ☐ 870 Taxes (U.S. Plaintiff or Defendant)
- ☐ 871 IRS-Third Party 26 USC 7609

OTHER STATUTES
- ☐ 400 State Reapportionment
- ☐ 410 Antitrust
- ☐ 430 Banks and Banking
- ☐ 450 Commerce/ICC
- ☐ 460 Deportation
- ☐ 470 Racketeer Influenced & Corrupt Organizations
- ☐ 810 Selective Service
- ☐ 850 Securities/Commodities/ Exchange
- ☐ 875 Customer Challenge 12 USC 3410
- ☐ 891 Agricultural Acts
- ☐ 892 Economic Stabilization Act
- ☐ 893 Environmental Matters
- ☐ 894 Energy Allocation Act
- ☐ 895 Freedom of Information Act
- ☐ 900 Appeal of Fee Determination Under Equal Access to Justice
- ☐ 950 Constitutionality of State Statutes
- ☐ 890 Other Statutory Actions

V. ORIGIN (PLACE AN "X" IN ONE BOX ONLY)

- ☒ 1 Original Proceeding
- ☐ 2 Removed from State Court
- ☐ 3 Remanded from Appellate Court
- ☐ 4 Reinstated or Reopened
- ☐ 5 Transferred from another district (specify)
- ☐ 6 Multi district Litigation
- ☐ 7 Appeal to District Judge from Magistrate

VI. CAUSE OF ACTION (Cite the U.S. Civil Statute under which you are filing and write brief statement of cause. Do not cite jurisdictional statutes unless diversity.)

This is a civil action arising under the patent laws of the United States, more particularly 35 U.S.C. Sections 271, 281, 283, 284 and 285.

VII. REQUESTED IN COMPLAINT: ☐ CHECK IF THIS IS A CLASS ACTION UNDER F.R.C.P. 23

$DEMAND Damages in excess of $75,000

CHECK YES only if demanded in complaint: JURY DEMAND: ☒ Yes ☐ No

VIII. RELATED CASE(S) (See instructions): IF ANY

JUDGE ______ DOCKET NUMBER ______

DATE 11/10/05

SIGNATURE OF ATTORNEY OF RECORD

...SUANT TO LOCAL RULE 83.11

1. Is this a case that has been previously dismissed?

☐ Yes
☒ No

If yes, give the following information:

Court: ______________________________

Case No.: ______________________________

Judge: ______________________________

2. Other than stated above, are there any pending or previously discontinued or dismissed companion cases in this or any other court, including state court? (Companion cases are matters in which it appears substantially similar evidence will be offered or the same or related parties are present and the cases arise out of the same transaction or occurrence.)

☐ Yes
☒ No

If yes, give the following information:

Court: ______________________________

Case No.: ______________________________

Judge: ______________________________

Notes :